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RESEARCH MEMORANDUM

LOW-SPEED INVESTIGATION OF THE EFFECTS OF WING TANKS AND SPEED BRAKES ON THE STATIC STABILITY OF A MODEL HAVING A 40° SWEPT WING

By William C. Sleeman, Jr., and William J. Alford, Jr.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

A low-speed wind-tunnel investigation was conducted to study the effects of pylon-mounted wing tanks and speed brakes on the static stability characteristics of a model having sweptback wing and tail surfaces. The wing of the model was of aspect ratio 3.45 and was swept 40° at the quarter-chord line. The wing tanks were of fineness ratio 10.4 and were located at approximately the 22-percent-wing-semispan station. The speed brakes were located on the sides of the fuselage a short distance behind the wing trailing edge.

The test results indicated that addition of the tanks and brakes had an appreciable adverse effect on the directional stability characteristics of the model throughout the sideslip range. Furthermore, rudder effectiveness with the tanks and brakes installed was such that sideslip angles corresponding to regions of very low directional stability could be closely approached. In addition to the directional-stability problems encountered, a large variation of pitching moment with sideslip (nose down with increased sideslip) revealed a longitudinal trim problem that could be encountered in flight for an airplane having similar characteristics and for which large sideslip angles could be reached inadvertently.

An increase in size of the vertical tail and the addition of a dorsal fin offered two possible means for improving the yawing-moment characteristics with tanks and brakes installed.

INTRODUCTION

During flight testing of several current high-speed airplane configurations, some conventional maneuvers such as abrupt aileron rolls and rudder kicks (ref. 1 and unpublished data) have led to violent uncontrolled lateral and longitudinal motions. Although these airplanes differed appreciably in geometry, their flight behavior was characterized by the attainment of large positive and negative angles of attack as well as high sideslip angles within a given flight record. For one airplane configuration, the violent motion encountered appeared to be associated with the installation of wing tanks and projection of speed brakes. Flight tests of this airplane also indicated that the aforementioned undesirable characteristics were present at both low speeds and high speeds. It appeared therefore that some research at low speed on a typical configuration could provide static stability information pertinent to this problem and of general interest relative to the longitudinal and lateral characteristics over a large range of sideslip angle and angles of attack.

An investigation has been conducted in the Langley 300 mph 7- by 10-foot tunnel to determine the effects of pylon-mounted wing tanks and speed brakes on the static stability characteristics of a complete model having a 40° sweptback wing of aspect ratio 3.45. Static longitudinal and lateral characteristics of a model differing only slightly in tail geometry from the present model are presented in reference 2. Results of this investigation are presented as the variation of aerodynamic characteristics with sideslip angle for a range of sideslip angles from -4° to 30°. Although most of the test results were obtained with the model at an angle of attack of 0.3°, the effects of tanks and brakes on the basic model were also determined over the aforementioned sideslip range at angles of attack of approximately $\pm 13^{\circ}$ and $\pm 6^{\circ}$.

Test results for the basic configuration indicated that a marked reduction in directional stability accompanied the addition of wing tanks and speed brakes. Much of the investigation was therefore directed toward determination of the causes of these adverse effects and determining means for attaining more satisfactory characteristics with tanks and brakes installed.

COEFFICIENTS AND SYMBOLS

The results of this investigation are presented as standard NACA coefficients of forces and moments. Figure 1 shows the stability system of axes and the positive direction of forces, moments, and displacements of the model. Moment coefficients are given about the reference center shown in figure 2 (located on the fuselage center line at a longitudinal position corresponding to the 25-percent-mean-aerodynamic-chord station).

C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_X	longitudinal-force coefficient, $\frac{X}{qS}$
C_D	drag coefficient, $-C_X$ at zero sideslip
C_m	pitching-moment coefficient, $\frac{M}{qS\bar{c}}$
C_l	rolling-moment coefficient, $\frac{L}{qSb}$
C_n	yawing-moment coefficient, $\frac{N}{qSb}$
C_Y	lateral-force coefficient, $\frac{Y}{qS}$
X	longitudinal force along X-axis, lb
Y	lateral force along Y-axis, lb
Z	vertical force along Z-axis (Lift = -Z), lb
L	rolling moment about X-axis, ft-lb
M	pitching moment about Y-axis, ft-lb
N	yawing moment about Z-axis, ft-lb
q	dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft
V	velocity, ft/sec
ρ	air density, slugs/cu ft
S	wing area (excluding simulated wing root inlet), sq ft
b	wing span, ft
$\bar{c}$	wing mean aerodynamic chord, ft
α	angle of attack of fuselage center line, deg
β	angle of sideslip, deg

δ_r — rudder deflection measured in a plane parallel to the fuselage center line, positive when trailing edge is to the left, deg

δ_{a_T} — total or combined deflection of left and right ailerons measured in a plane normal to the wing quarter-chord line, deg

$C_{l_T}, C_{n_T}, C_{Y_T}$ — denotes coefficient increments due to the tail surfaces

MODEL DESCRIPTION

Side and plan views of the basic model configuration used in this investigation are given as figure 2. The wing had 40° sweepback of the quarter-chord line, aspect ratio 3.45, taper ratio 0.578, and had NACA 64A010 airfoil sections normal to the quarter-chord line. A summary of the geometric characteristics of the model is given in table I.

Principal dimensions and location of the fineness-ratio-10.4 wing tanks and the speed brakes are given in figure 3 and ordinates of the wing tanks are given in table II. Figure 3 also shows several modifications to the basic model which were tested in attempts to improve the directional stability. For the test without the canopy, a section of the fuselage containing the canopy was replaced by a section which continued the basic fuselage contour.

In the designation of model configurations, the basic model as shown in figure 2, with the exception of the landing gear, is considered the basic arrangement. Test results showing effects of the addition of tanks and brakes to the model are for the basic configuration unless otherwise indicated.

TESTS AND RESULTS

Test Conditions

Tests were conducted in the Langley 300 mph 7- by 10-foot tunnel at a dynamic pressure of 34.2 pounds per square foot, which corresponds to an airspeed of approximately 116 miles per hour. The test Reynolds number based on the wing mean aerodynamic chord was approximately 1.8×10^6.

The model was mounted in the tunnel on a single-support strut, which was attached to the fuselage, and practically all the tests were made by varying the angle of sideslip with the angle of attack remaining constant.

Corrections

Jet-boundary corrections to the angle of attack and the longitudinal-force coefficients were determined from reference 3. The following corrections were added to the data:

$$\Delta\alpha = 1.02C_L \text{ (deg)}$$

$$\Delta C_X = -0.0155{C_L}^2$$

$$\Delta C_m = 0.0143C_L \text{ (for tail-on tests only)}$$

Blockage corrections determined from reference 4 were applied to the dynamic pressure.

No systematic evaluation of support tares has been made and corrections for support interference have not been applied to the data. However, results of some limited tare tests on this model and past experience indicated that support tares were probably small and associated primarily with minimum drag and longitudinal trim.

Presentation of Results

Most of the basic results are presented as variations of the aerodynamic characteristics with sideslip angle for the various test configurations. Some results showing the longitudinal characteristics of the model at zero sideslip with and without tanks and brakes are given in figure 4. Effects of the tanks and brakes on the aerodynamic characteristics in sideslip of the basic configuration for several constant values of angle of attack are given in figure 5. Characteristics of the basic configuration with the rudder and ailerons deflected are also presented in figures 6 and 7, respectively. Results showing effects of the canopy are given in figure 8 and characteristics of the model with the tail surfaces removed are presented in figure 9.

Tests were conducted with the tanks and brakes installed separately in order to assess the individual contribution of these components and these results are given in figure 10. Results showing the effects of various modifications such as addition of the landing gear, tank fins, dorsal fins, extended vertical tail, and flap deflection are presented in figures 11 to 18.

Inasmuch as the effects of many of the individual components and modifications cannot be conveniently obtained directly from the basic data figures, the most pertinent information is presented in the summary figures 19 to 25.

DISCUSSION

The present investigation was primarily concerned with the possible problems associated with addition of wing tanks and speed brakes on the directional characteristics of the model; however, limited tests also were made to determine the effects of tanks and brakes on the longitudinal characteristics at zero sideslip over an angle-of-attack range of approximately $\pm 19^{\circ}$. These results, presented in figure 4, show no large effects of tanks and brakes on the longitudinal characteristics other than the expected increase in drag.

Basic Configuration

Effect of tanks and brakes.- The effects of tanks and brakes on the aerodynamic characteristics in sideslip of the basic configuration are shown in figure 5 for several constant values of angle of attack. The directional stability near zero sideslip was reduced approximately in half at positive angles of attack (figs. 5(c), 5(d), and 5(e)) by addition of the tanks and brakes. For example, the parameter $C_{n_{\beta}}$ was reduced from a value of about 0.0022 at $\alpha = 0.3^{\circ}$ to a value of 0.0010 by installation of the tanks and brakes (fig. 5(c)). Regions of neutral directional stability were indicated at approximately 20° sideslip for the basic clean configuration at all angles of attack. Addition of the tanks and brakes caused this neutral stability to occur at sideslip angles somewhat less than 20°. In general, throughout the angle-of-attack range, addition of the tanks and brakes increased the dihedral effect (rolling moment due to sideslip) at low sideslip angles; however, at higher sideslip angles, negative dihedral effect was indicated both with and without the tanks and brakes. Inasmuch as the characteristics through the sideslip range obtained at $\alpha = 0.3^{\circ}$ were typical of those obtained at other angles of attack, subsequent tests were made only at this angle of attack.

The results presented in figure 5 were obtained with the ailerons and the rudder on the model undeflected and it should be pertinent to determine if the aforementioned adverse effects of tanks and brakes persisted with these controls deflected. Aerodynamic characteristics of the model with the rudder deflected 13.5° and with the ailerons deflected 20° are presented in figures 6 and 7, respectively, for an angle of attack of 0.3°. Comparison of figures 6 and 7 with figure 5(c) indicates that deflection of the controls had little effect on the increments attributable to addition of the tanks and brakes. The rolling moment due to sideslip was more linear at low sideslip angles with the controls deflected (figs. 6 and 7); however, negative dihedral effect was still indicated at higher sideslip angles. The rudder effectiveness with the tanks and brakes installed was such that regions of very low directional stability could be closely approached. This low stability combined with dynamic overshoot would allow an airplane having these characteristics to reach high sideslip angles inadvertently.

Pitching-moment characteristics in sideslip.- An interesting aspect, not normally emphasized in lateral-stability investigations, was the pitching-moment variation with sideslip angle both with and without tanks and brakes installed. Figure 19 has been prepared to summarize the pitching-moment characteristics presented in figure 5 for the model with tanks and brakes installed. The pitching moment at zero sideslip has been subtracted from the data of figure 5 so that the curves of figure 19 show only the increment of pitching moment due to sideslip at each test angle of attack. These results show large variations in pitching moment as the sideslip angle was increased above approximately 5° and indicate a strong diving tendency which increases generally with both angle of attack and sideslip. This pitching-moment variation combined with the low directional stability with the tanks and brakes installed would be highly undesirable from the standpoint of flight behavior of an airplane possessing these characteristics. With regard to the adverse pitching-moment characteristics, it would therefore be desirable to reduce this pitching-moment variation or increase the directional stability with tanks and brakes installed so that high sideslip angles could not be easily reached inadvertently. Attempts accordingly were made to find the causes of this pitching-moment variation and to attain means for eliminating or reducing its effects.

Results obtained with the tail surfaces removed are also given in figure 19 for an angle of attack of 0.3° and comparison of these results with the tail-on curves indicates that essentially all of the pitching-moment variation at this angle of attack was associated with the presence of the tail surfaces. An explanation of this pitching moment can be made from examination of the tuft grid photograph of the flow field near the tail presented in figure 20. This photograph was obtained from a previous investigation of this model mounted on wing support struts and in which the tail surfaces were replaced by thin rods indicating locations of the vertical tail and low, mid, and high positions of the horizontal tail. The mid horizontal-tail position in figure 20 corresponds closely to that of the present investigation. The flow field as indicated by the tufts shows the strong vortex from the trailing wing tip, the less extensive vortex from the leading wing tip, and a third centrally located vortex of approximately the same extent as the trailing-wing vortex. This central vortex was counterclockwise at positive sideslip angles which induced an upload on the horizontal tail at positive angles of attack where the tail had moved down into the vortex field. Flow surveys obtained with a single tuft probe showed that the horizontal tail moved away from the vortex as the angle of attack was decreased and the converse was observed with increasing angle of attack. Further probe surveys revealed that the vortex originated on top of the fuselage at the canopy and trailed along the upper side of the fuselage back to approximately the 3/4 length where it detached and trailed over the horizontal tail.

Attempts were made to eliminate the fuselage vortex by removing the canopy, inasmuch as the vortex appeared to originate at the canopy. The force data, which are presented in figure 8, and tuft surveys showing effects of the canopy, were consistent in that little difference was observed in the fuselage vortex and in the pitching-moment variation with sideslip with and without the canopy. It would therefore appear that relocation of the horizontal tail would be a more effective means of reducing the pitching-moment variation than attempting fuselage modifications.

<u>Tail contribution in sideslip</u>.- Increments of the lateral components due to the vertical and horizontal tail surfaces were determined from figures 5(c) and 9 and are presented in figure 21. A comparison of the rolling-moment characteristics with and without the tail surfaces (figs. 5(c) and 9) indicates that most of the dihedral effect at low sideslip angles was associated with the tail contribution. As indicated in figure 21, effects of tanks and brakes on the rolling-moment contribution of the tail were small.

Increments attributable to the tanks and brakes on the tail contribution to yawing moment and lateral force were fairly small, particularly at low and moderate sideslip angles where these effects were appreciably adverse for the complete model configuration. These results indicate therefore that the unfavorable effects of the tanks and brakes on directional stability of the complete model were primarily associated with their direct contribution on the wing-fuselage configuration rather than on the tail contribution.

<u>Individual effects of tanks and brakes</u>.- Results showing effects of tanks and brakes installed separately were obtained from figures 5(c) and 10 and are presented in figure 22. The largest individual effect on yawing moments shown in figure 22 was obtained with addition of the wing tanks for sideslip angles above approximately 10° and the combined effects of tanks and brakes were, in general, somewhat less than directly additive. A comparison of results presented in figure 11 with those of figure 10 would indicate that the adverse contribution of the tank pylons to directional stability was fairly small and therefore most of the effect of the tank installation was associated with the direct contribution of the tanks themselves.

Modifications to the Basic Configuration

Tank fins and brake modifications.- Inasmuch as the wing tanks were shown to have the largest adverse effect on directional stability, an attempt was made to reduce this effect by adding tail fins to the tanks as shown in figure 3. Results obtained with the tank fins on, both with and without brakes installed, are presented in figure 12 and show only small improvements with fins on the tanks.

Two modifications to the speed brakes were investigated in attempts to reduce the adverse contribution of the brakes and these results are given in figure 13. Comparison of figure 5(c) with figure 13 indicates that sealing the holes in the brakes or moving the brakes rearward produced little change in the directional characteristics of the model.

On the basis of the results considered thus far, it appears that more satisfactory directional characteristics must be achieved by improving the basic tail contribution rather than by reducing the adverse effects of the tank and brake arrangement on this model.

Extended vertical tail and dorsal fin.- Tests were made with the tip of the vertical tail extended as shown in figure 3 and these results are summarized in figure 23. Addition of the tip extension to the basic configuration with tanks and brakes resulted in an appreciable improvement in directional stability at low sideslip angles; however, the directional stability at sideslip angles above 15° was essentially zero with the extended tip. In order to achieve additional gains in stability at the higher sideslip angles, a large dorsal fin (see fig. 3) was installed on the model. Results showing effects of the extended tip with the large dorsal fin installed are also given in figure 23 and these results show that significant gains over the basic configuration could be realized by combination of the large dorsal fin and extended tip. The extent of these gains in directional stability is indicated in figure 24, which shows that the yawing-moment characteristics of the model with tanks and brakes installed could be made almost the same as for the basic clean configuration by addition of the large dorsal fin and the extended tip. A region of neutral directional stability exists, however, with these modifications above 15° sideslip, as in the case of the basic clean model.

Effect of dorsal fin size and landing gear.- Inasmuch as the large dorsal fin was made somewhat larger than might be considered adequate, tests were made of a smaller dorsal fin having the same length and approximately half the area of the large fin. Results obtained with the small dorsal fin presented in figure 24 show that the benefits achieved by the large dorsal fin were essentially retained up to a sideslip angle of approximately 20° - in fact, the small dorsal fin was superior to the large fin between 15° and 20° sideslip. Above this angle, the small fin afforded a significant improvement over the basic configuration; however, these gains were only about half of those obtained with the large fin.

The landing gear for this model (fig. 2) had appreciable projected side area and therefore could have a significant influence on the directional characteristics of the model. Effects of the landing gear with the large and small dorsal fins are shown in figure 25. For sideslip angles up to about 15° the landing gear had a relatively small effect; however, above this angle, addition of the landing gear had a fairly large unfavorable effect on yawing moments of the model for both dorsal-fin arrangements.

Effect of flap deflection.- Tests of the basic configuration with tanks and brakes installed were made to determine the effects of flap deflection on the directional characteristics of the model with the landing gear on, and these results are given in figure 18. Deflection of the wing flaps to 40° increased the value of C_{n_β} at low sideslip angles to approximately that of the basic clean model (0.0022); however, the characteristics at sideslip angles greater than 15° showed a fairly large region of instability followed by a region of neutral stability with flaps deflected. Test data with the extended tail and dorsal fin were not obtained for the flap-deflected condition; however, it might be expected that these modifications would materially improve the characteristics at the higher sideslip angles. Furthermore, inasmuch as flap deflection would normally be expected to accompany extension of the landing gear, the adverse effects of the landing gear shown in figure 25 would probably be counteracted to some extent by the favorable effect of flap deflection.

CONCLUSIONS

An investigation to determine the effects of wing tanks and speed brakes on the low-speed directional stability characteristics of a model having a 40° swept wing indicated the following conclusions:

1. Addition of tanks and brakes reduced the directional stability of the basic model at low sideslip angles by approximately 50 percent and had an adverse effect on the yawing-moment variation at higher sideslip angles.

2. Studies of modifications to the model such as increasing the vertical-tail size and installation of a dorsal fin indicated possible means for improving the yawing-moment characteristics with tanks and brakes installed.

3. The rudder effectiveness with tanks and brakes installed was such that sideslip regions of very low directional stability could be closely approached. This low directional stability combined with dynamic overshoot would allow an airplane having these characteristics to reach high sideslip angles inadvertently.

4. A large pitching-moment variation with sideslip angle was found for all configurations, which when combined with the low directional stability with tanks and brakes installed could be highly undesirable from the standpoint of flight behavior of an airplane having these characteristics.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 7, 1955.

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3. Gillis, Clarence L., Polhamus, Edward C., and Gray, Joseph L., Jr.: Charts for Determining Jet-Boundary Corrections for Complete Models in 7- by 10-Foot Closed Rectangular Wind Tunnels. NACA WR L-123, 1945. (Formerly NACA ARR L5G31.)

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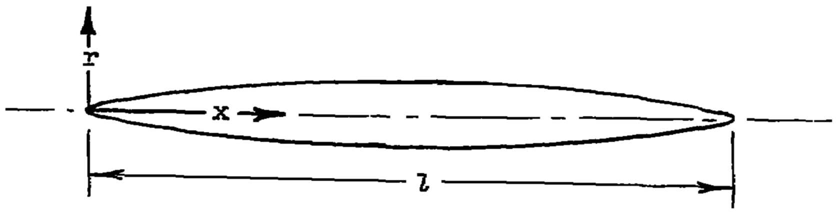
TABLE I

SUMMARY OF MODEL GEOMETRY

Wing:	
Area (not including simulated inlet area), sq ft	9.03
Span, ft	5.59
Sweepback of quarter-chord line, deg	40
Aspect ratio	3.45
Taper ratio	0.578
Dihedral, deg	-3.5
Incidence, deg	2.5
Geometric twist, deg	0
Mean aerodynamic chord, ft	1.67
Airfoil section (normal to quarter-chord line)	NACA 64A010
Flap:	
Type	Plain trailing edge
Area (one flap), sq ft	0.42
Span, ft	1.009
Hinge line, percent chord	75
Maximum deflection, deg	40
Aileron:	
Area (one aileron), sq ft	0.38
Span, ft	1.24
Hinge line, percent chord	75
Horizontal tail:	
Area, sq ft	1.55
Span, ft	2.36
Sweepback of quarter-chord line, deg	40
Incidence, deg	-1.0
Aspect ratio	3.54
Taper ratio	1.0
Chord, ft	0.67
Airfoil section	NACA 64A009
Tail length from $(\bar{c}/4)_{wing}$ to $(\bar{c}/4)_{tail}$, ft	3.45
Basic vertical tail:	
Area, sq ft	1.397
Span, ft	1.479
Sweepback of quarter-chord line, deg	41.56
Aspect ratio	1.57
Taper ratio	0.421
Mean aerodynamic chord, ft	0.997
Airfoil section (normal to quarter-chord line)	NACA $64_{(10)}$A011
Tail length from $(\bar{c}/4)_{wing}$ to $(\bar{c}/4)_{tail}$, ft	3.082
Vertical tail with extended tip:	
Area, sq ft	1.478
Span, ft	1.628
Sweepback of quarter-chord line, deg	41.56
Aspect ratio	1.79
Taper ratio	0.366
Mean aerodynamic chord, ft	0.973
Airfoil section (normal to quarter chord line)	NACA $64_{(10)}$A011
Tail length from $(\bar{c}/4)_{wing}$ to $(\bar{c}/4)_{tail}$, ft	3.125
Rudder:	
Type	Trailing-edge flap, internally balanced
Area, sq ft	0.289
Span, ft	1.263
Chord measured normal to hinge line, ft	0.205
Taper ratio	1.0
Sweepback of hinge line measured from normal to the fuselage center line, deg	26.5

TABLE II

WING-TANK ORDINATES



x/l	r/l	x/l
0	0	1.00
.02	.0104	.98
.04	.0156	.96
.06	.0197	.94
.08	.0237	.92
.10	.0274	.90
.12	.0303	.88
.16	.0349	.84
.20	.0383	.80
.24	.0411	.76
.28	.0432	.72
.32	.0450	.68
.36	.0465	.64
.40	.0474	.60
.44	.0479	.56
.48	.0481	.52
.50	.0482	.50
l = 46.833 in.		

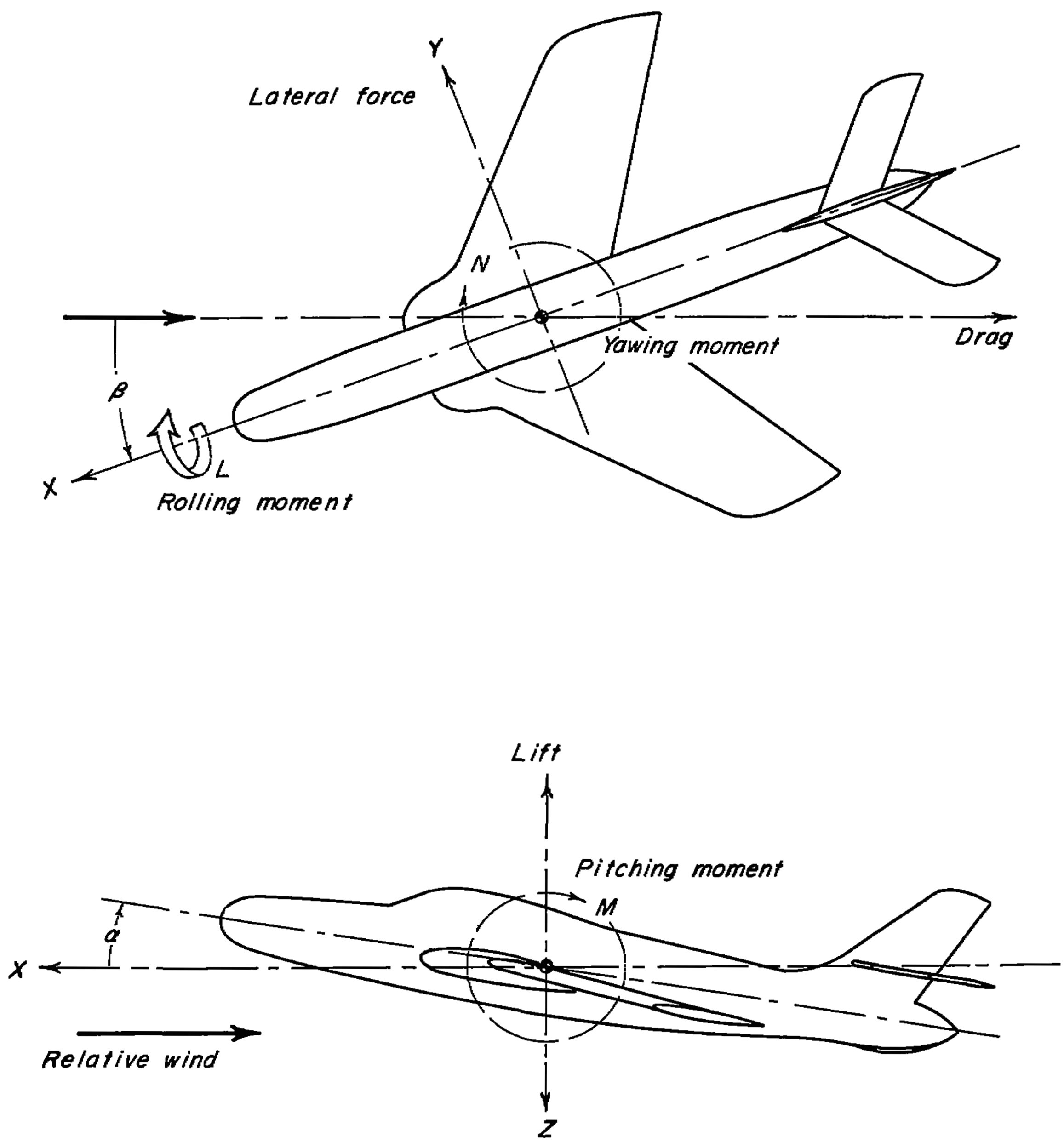


Figure 1.- Stability system of axes. Positive directions of forces, moments, and angles are indicated by arrows.

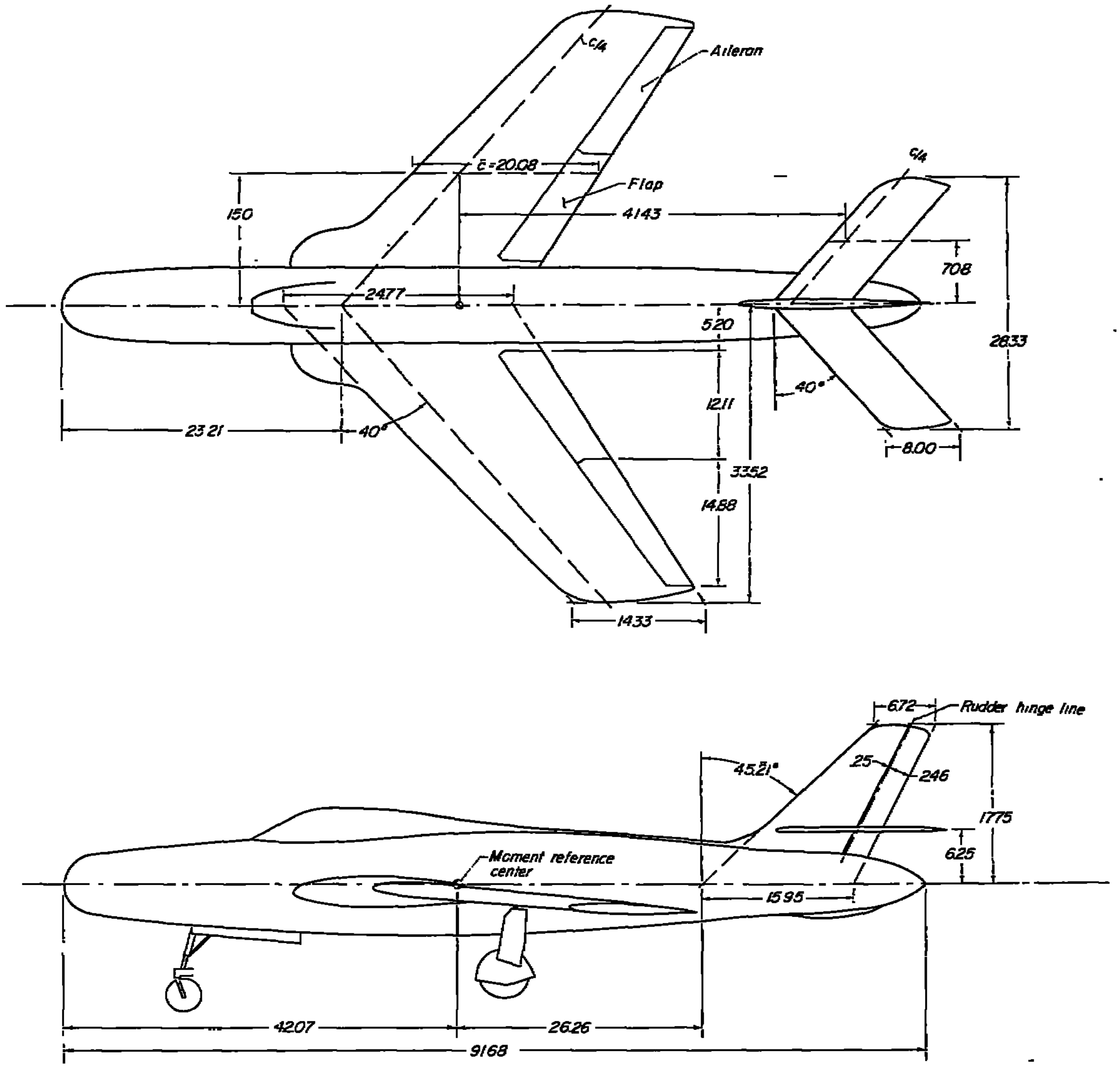


Figure 2.- General arrangement of the basic model configuration. (All dimensions are in inches.)

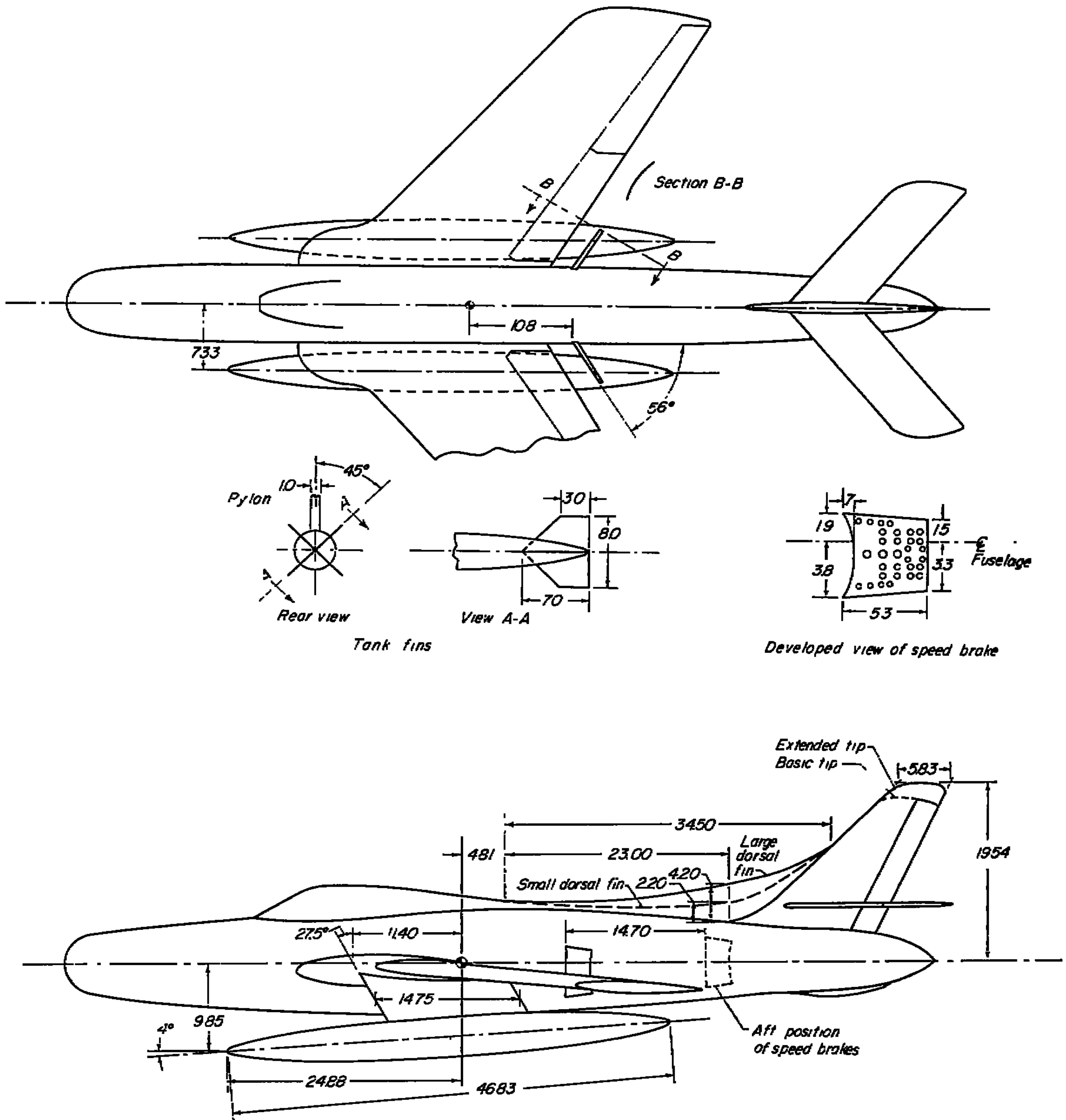


Figure 3.- Principal dimensions of wing tanks, speed brakes, and modifications to the basic configuration. (All dimensions are in inches.)

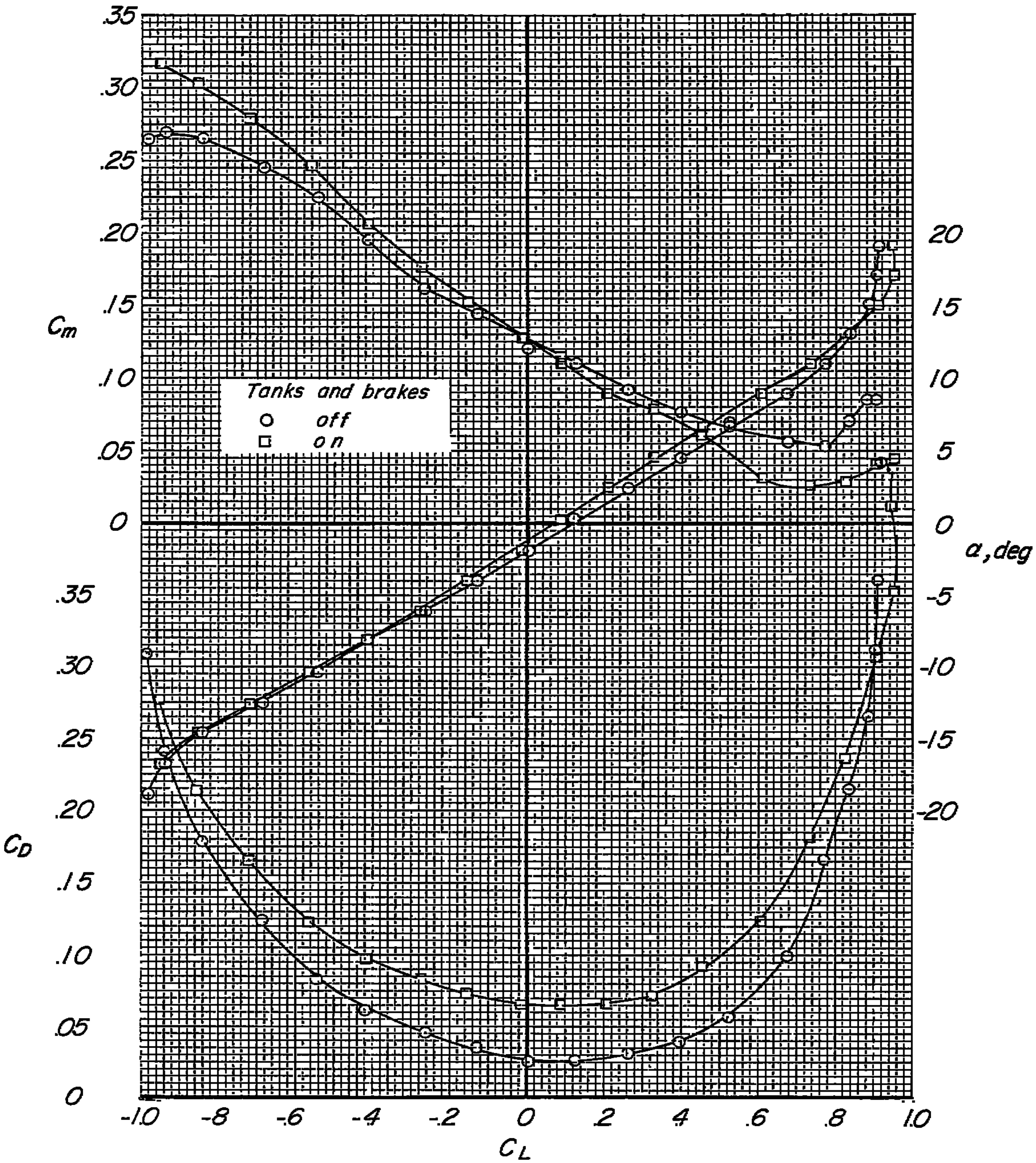
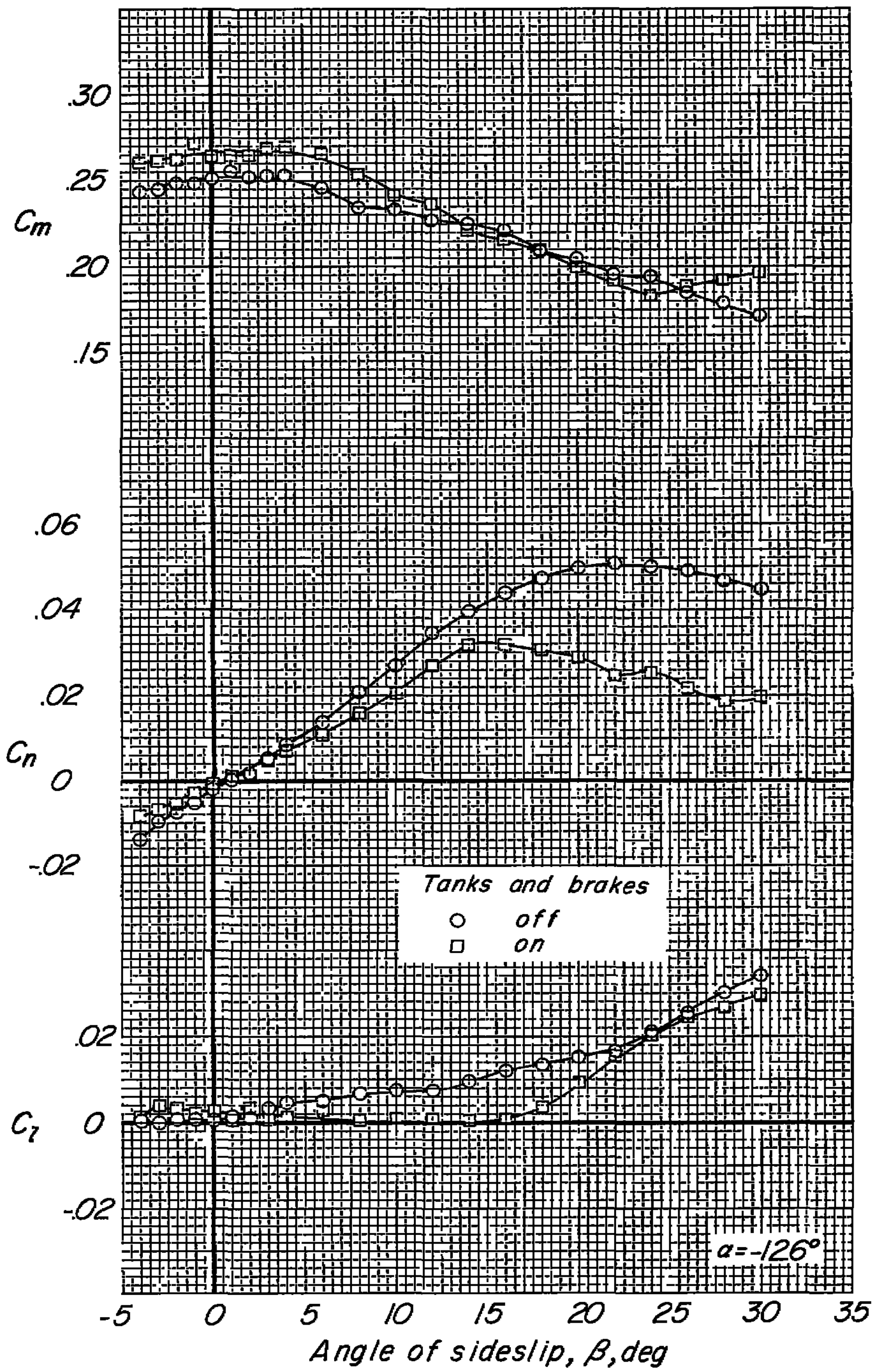
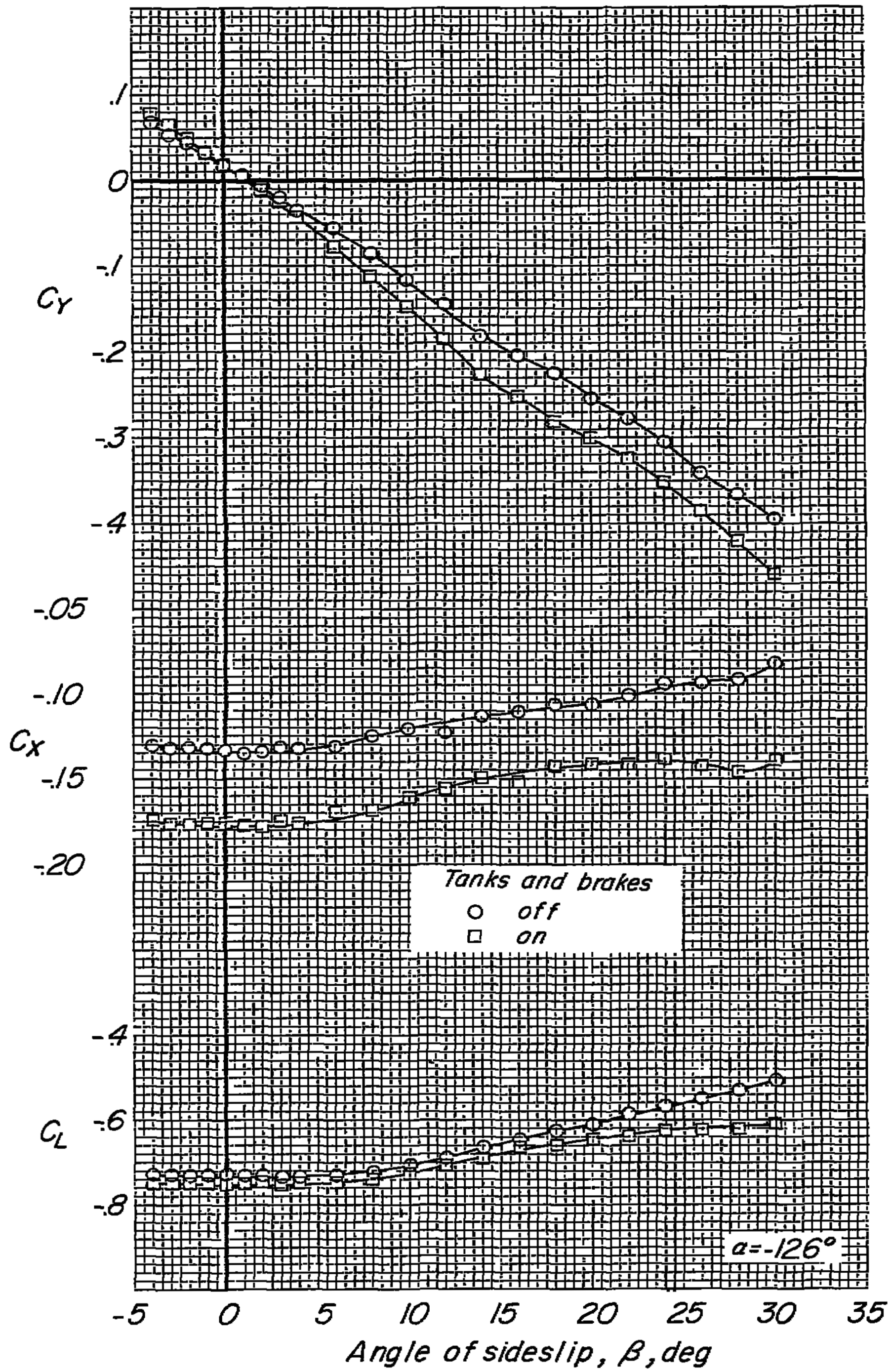


Figure 4.- Aerodynamic characteristics in pitch showing effects of tanks and brakes for the basic configuration. $\beta = 0^{\circ}$.



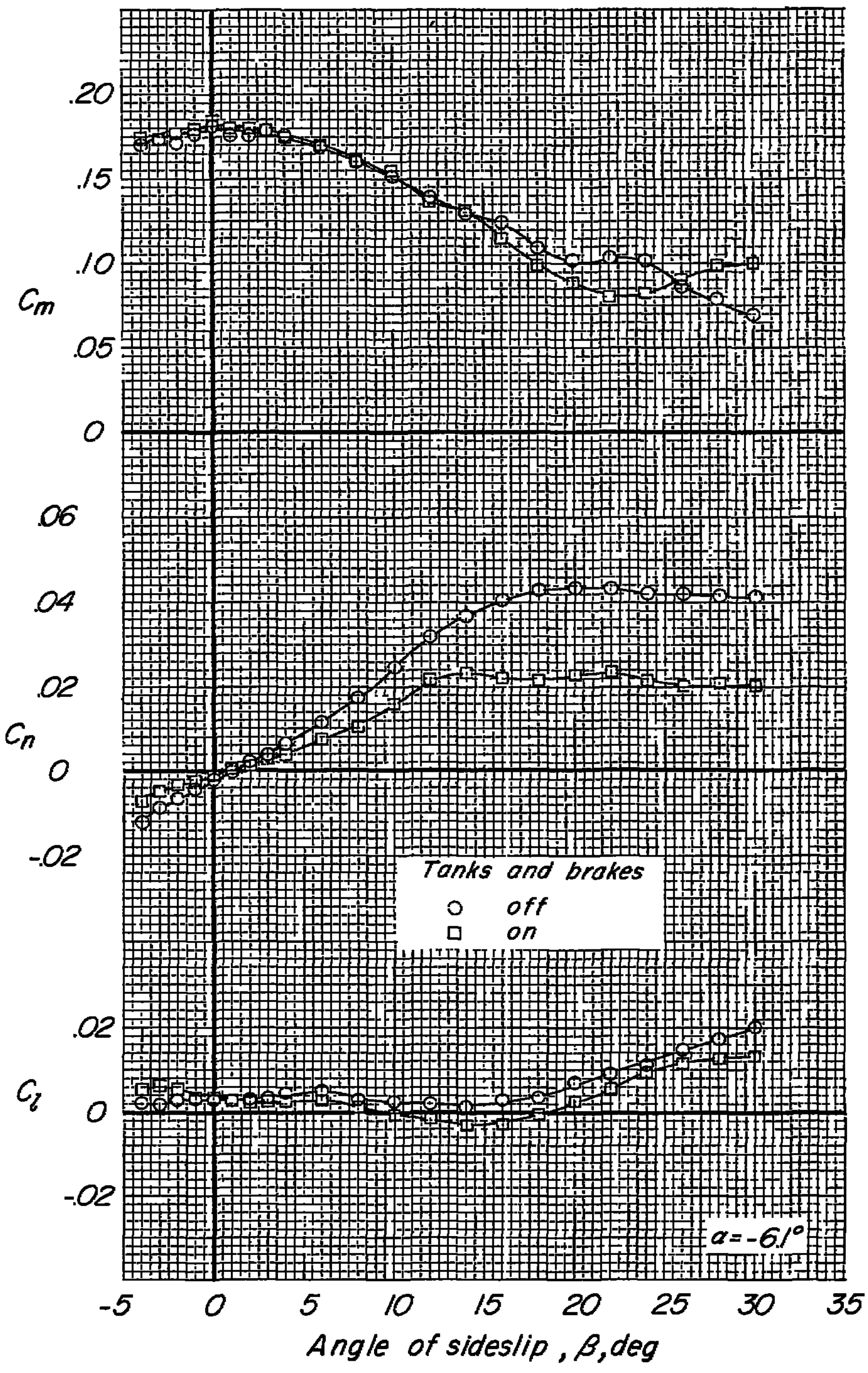
(a) $\alpha = -12.6^{\circ}$.

Figure 5.- Effect of tanks and brakes on the aerodynamic characteristics of the model in sideslip.



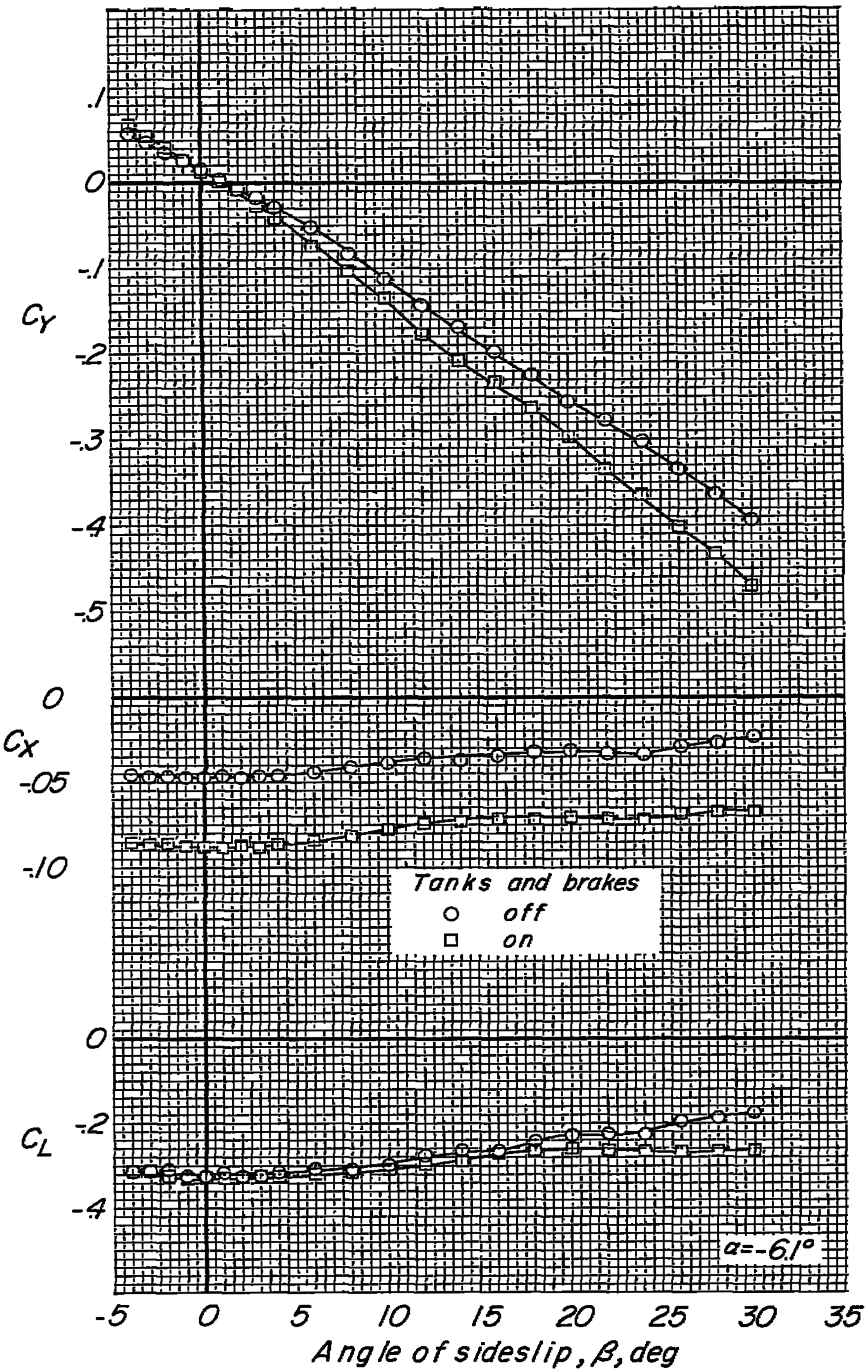
(a) Concluded.

Figure 5.- Continued.



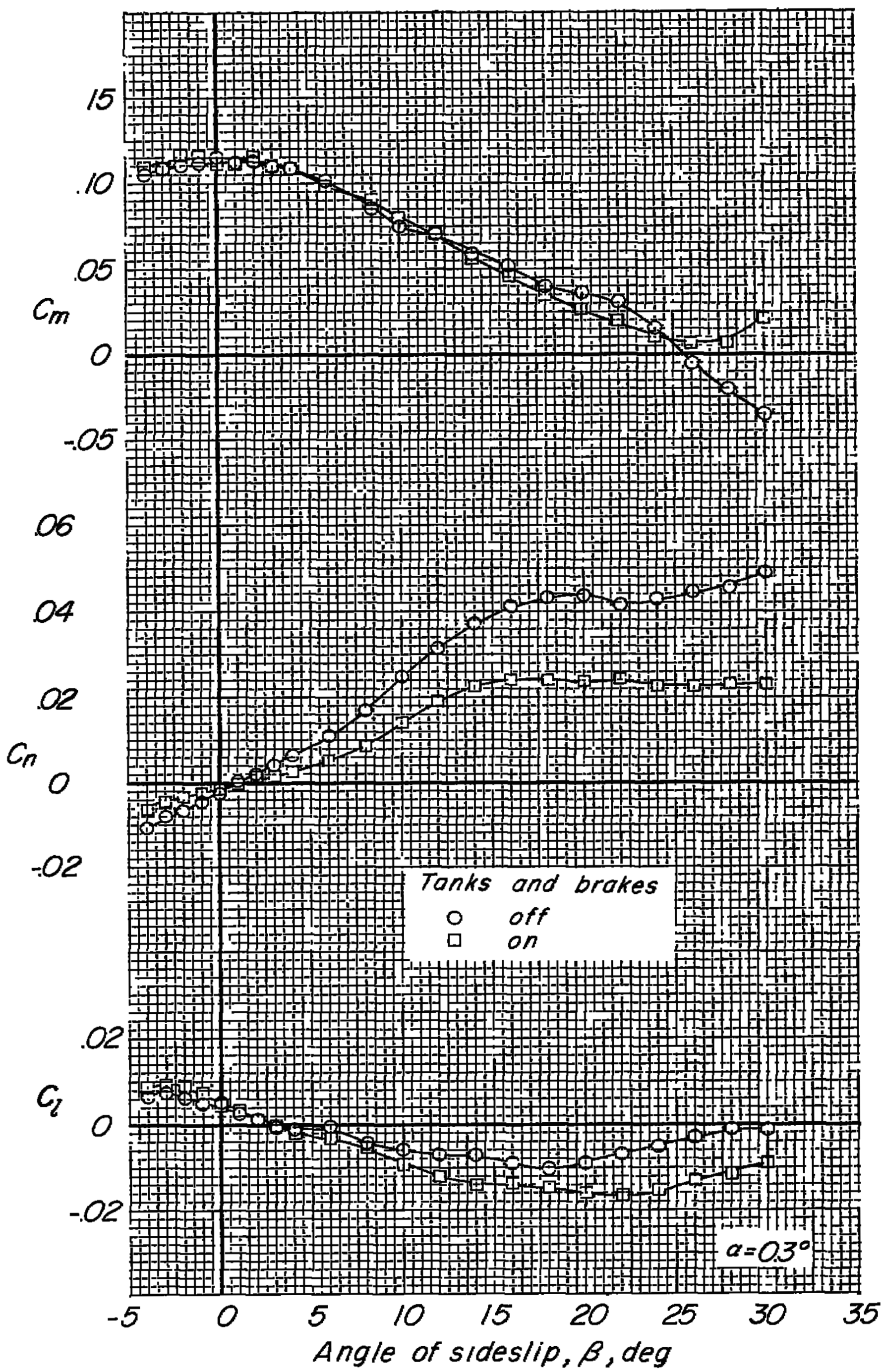
(b) $\alpha = -6.1^{\circ}$.

Figure 5.- Continued.



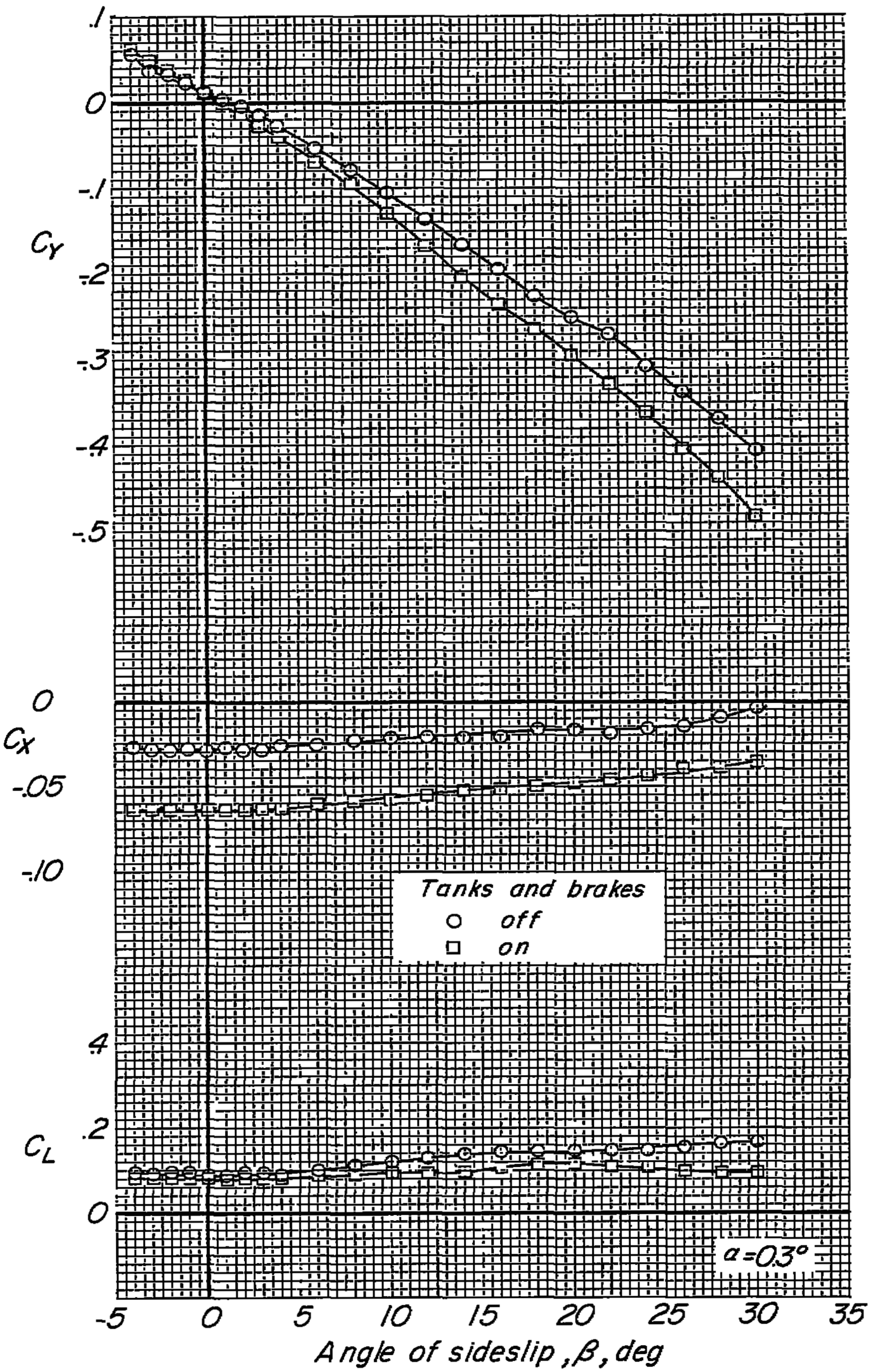
(b) Concluded.

Figure 5.- Continued.



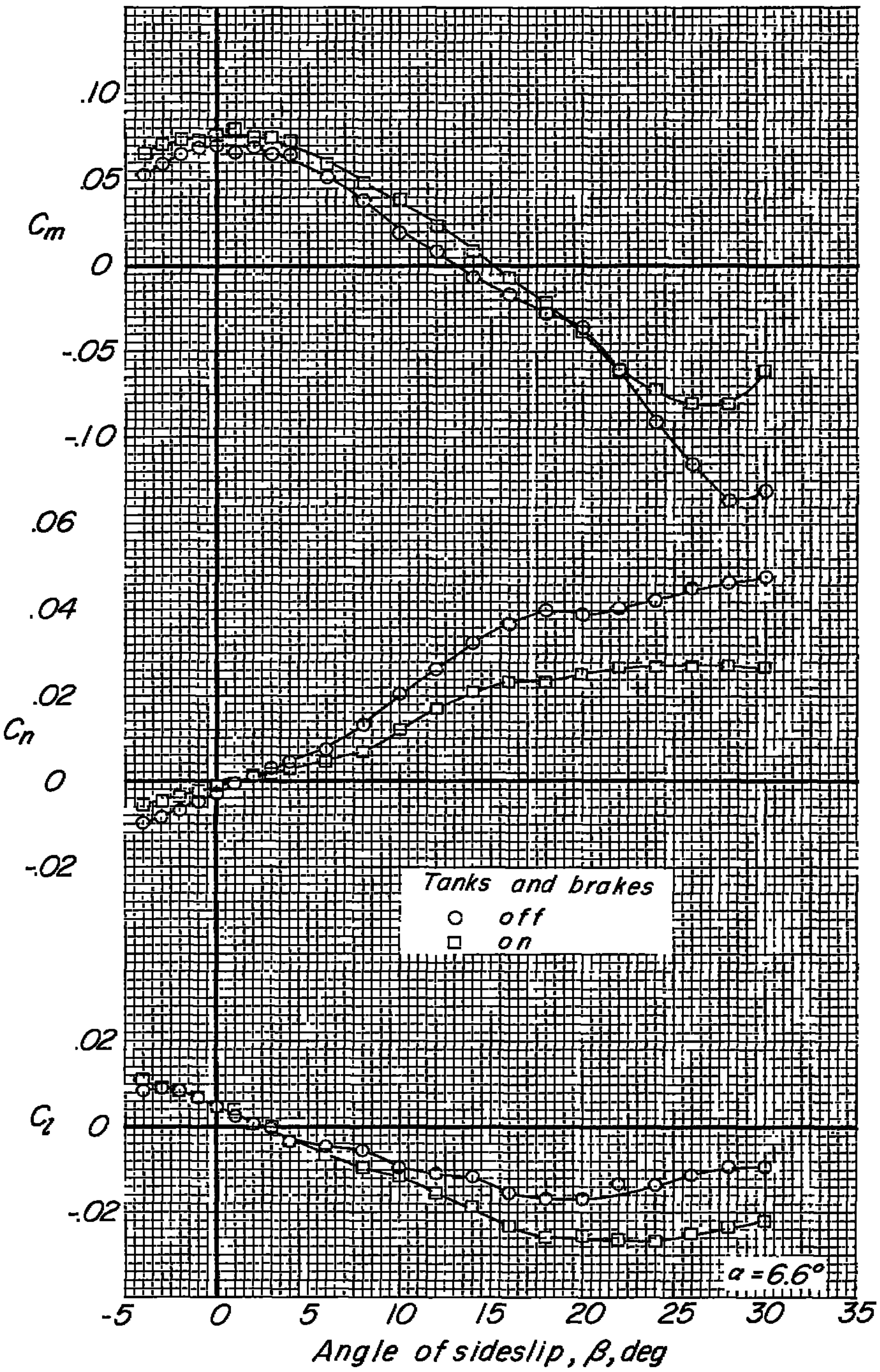
(c) $\alpha = 0.3^{\circ}$.

Figure 5.- Continued.



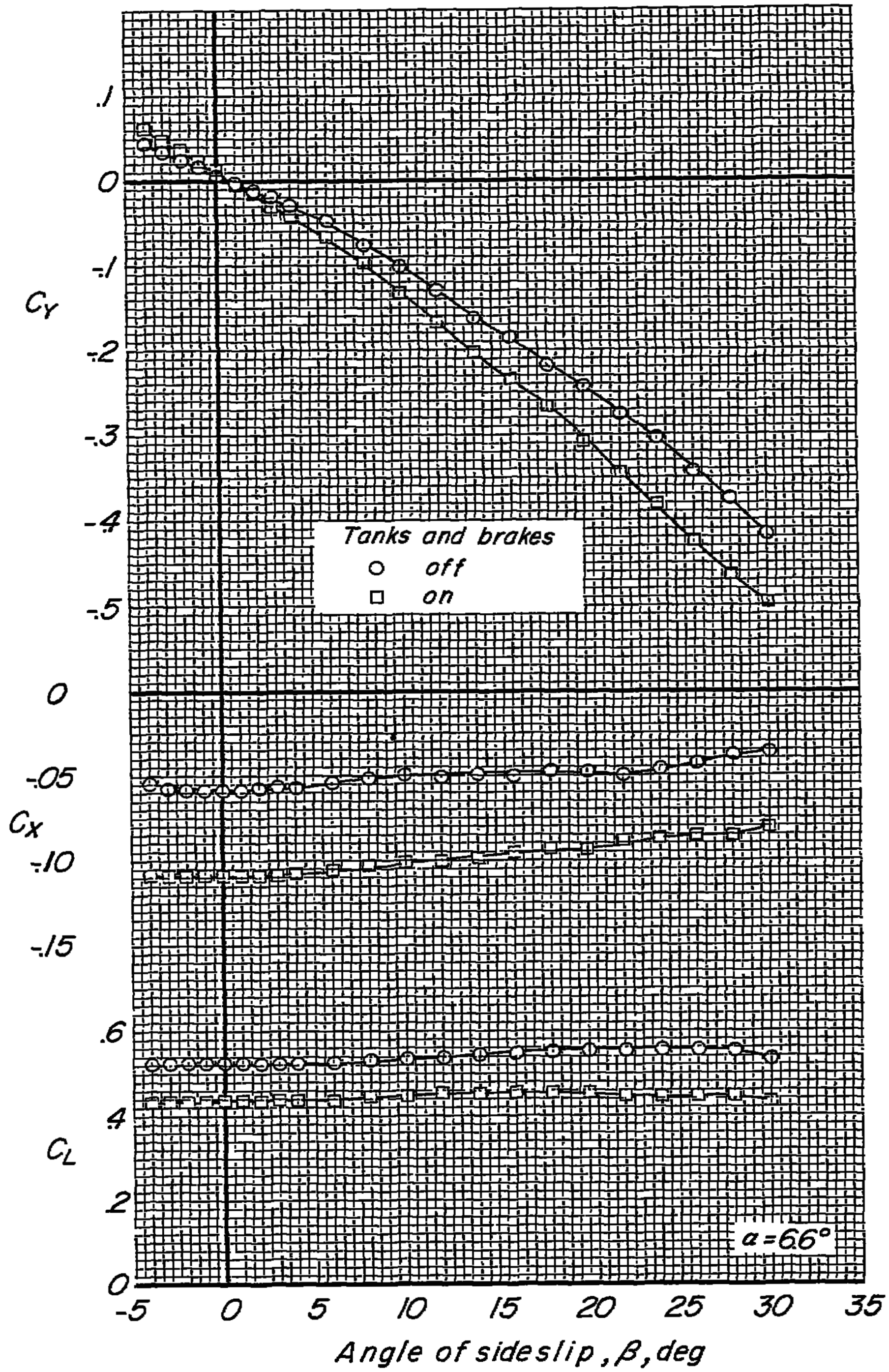
(c) Concluded.

Figure 5.- Continued.



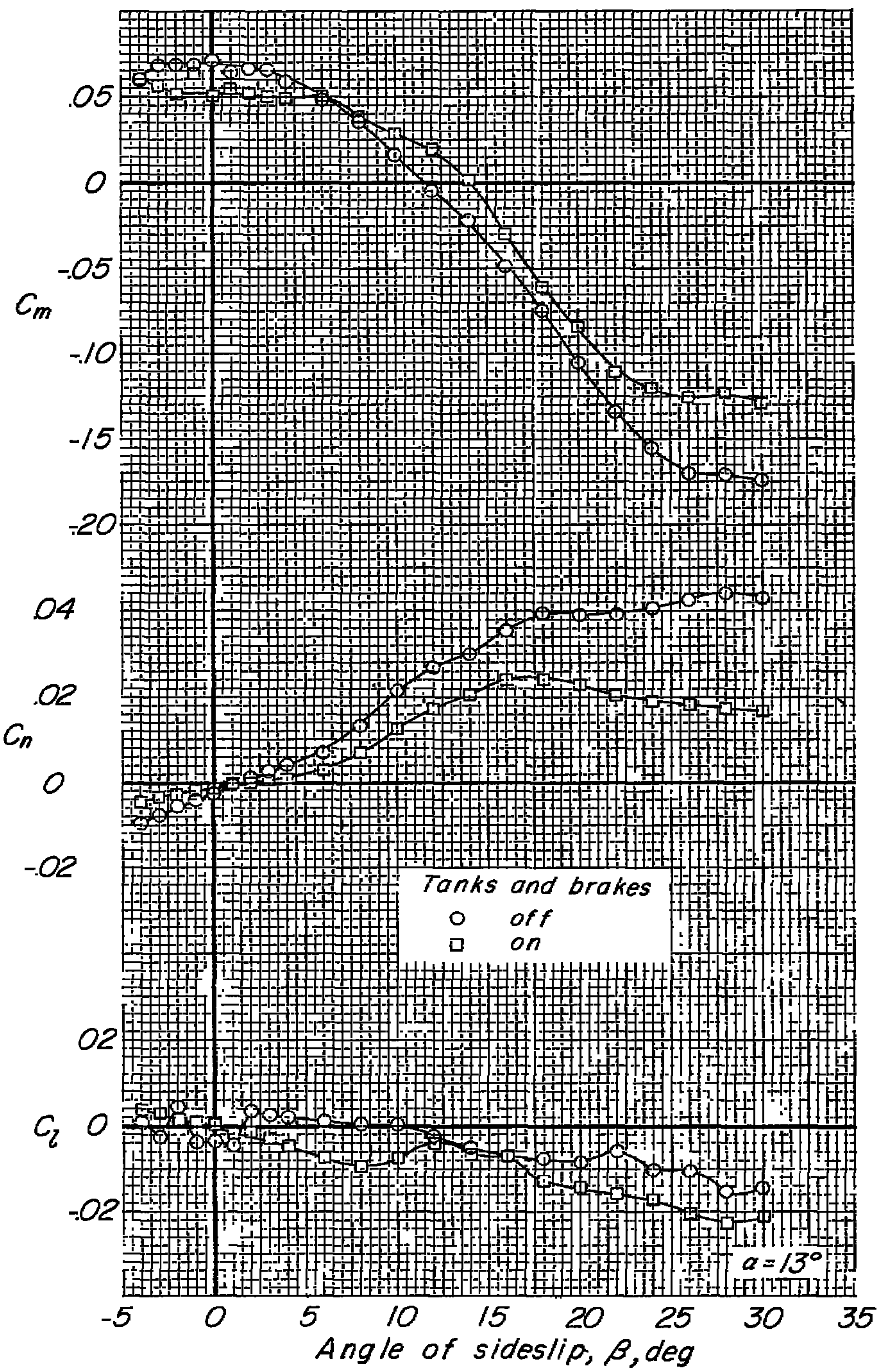
(d) $\alpha = 6.6^{\circ}$.

Figure 5.- Continued.



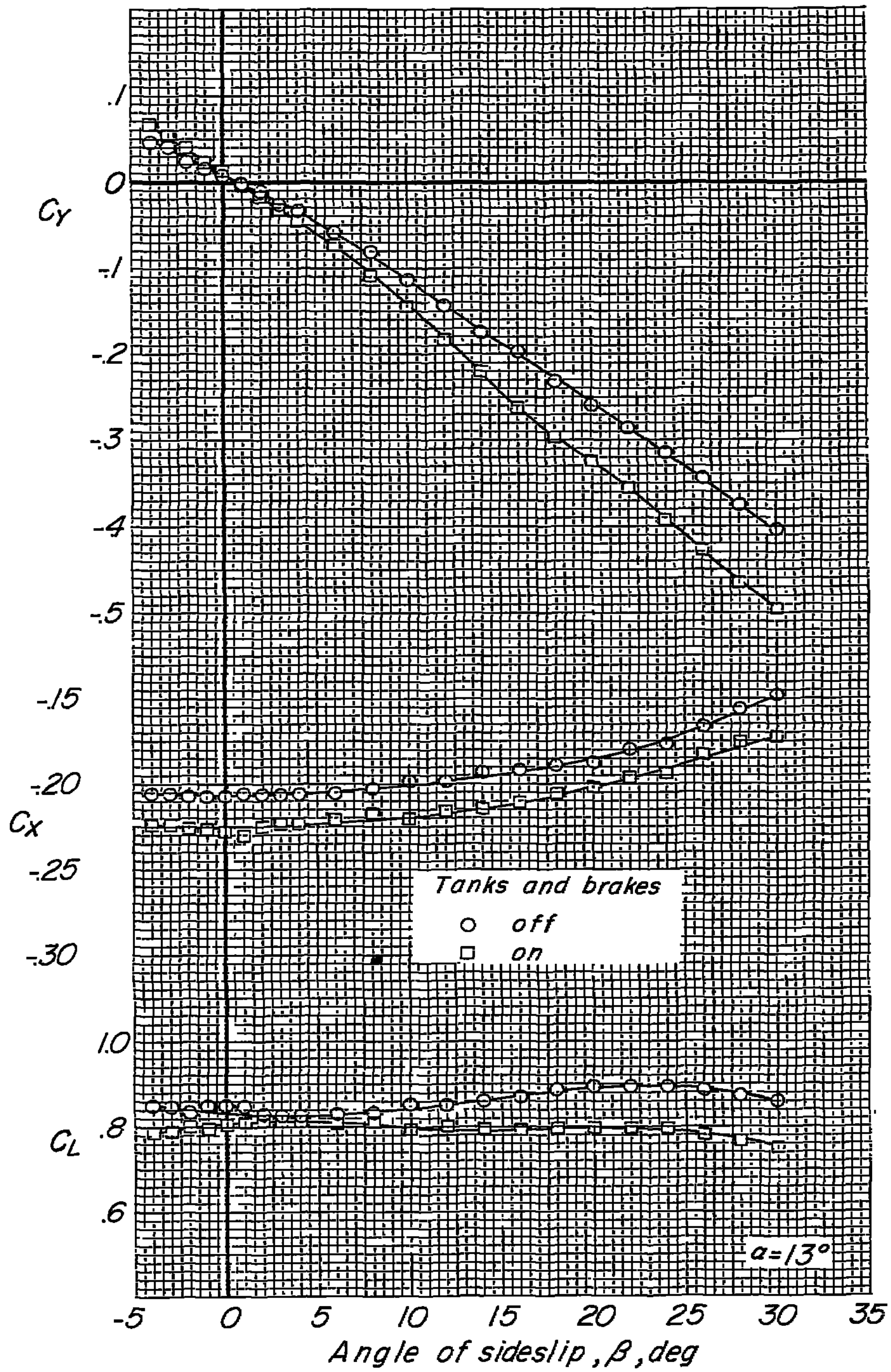
(d) Concluded.

Figure 5.- Continued.



(e) $\alpha = 13.0°$.

Figure 5.- Continued.



(e) Concluded.

Figure 5.- Concluded.

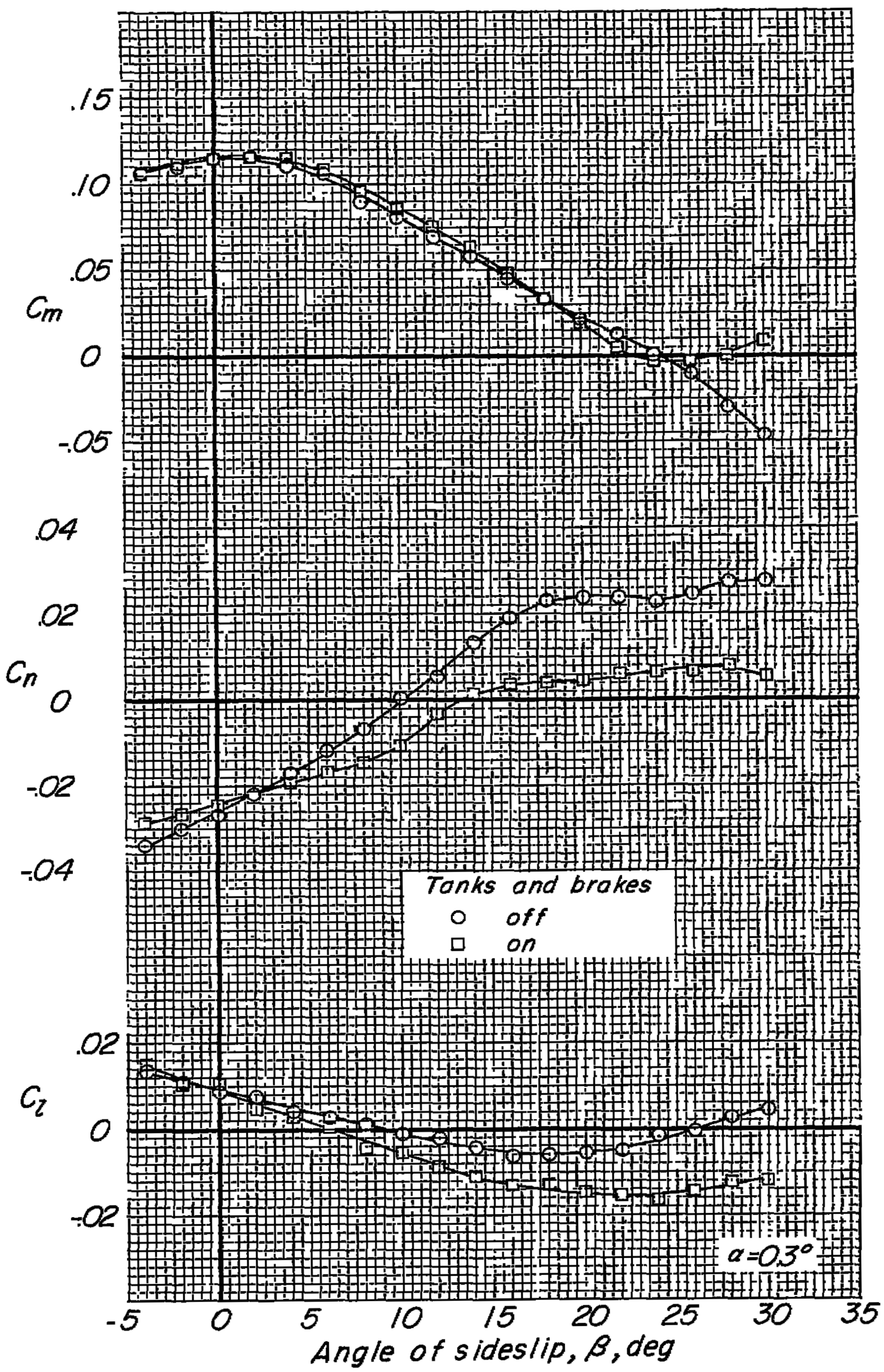


Figure 6.- Effect of tanks and brakes on the aerodynamic characteristics of the model with the rudder deflected. $\delta_r = 13.5^\circ$; $\alpha = 0.3^\circ$.

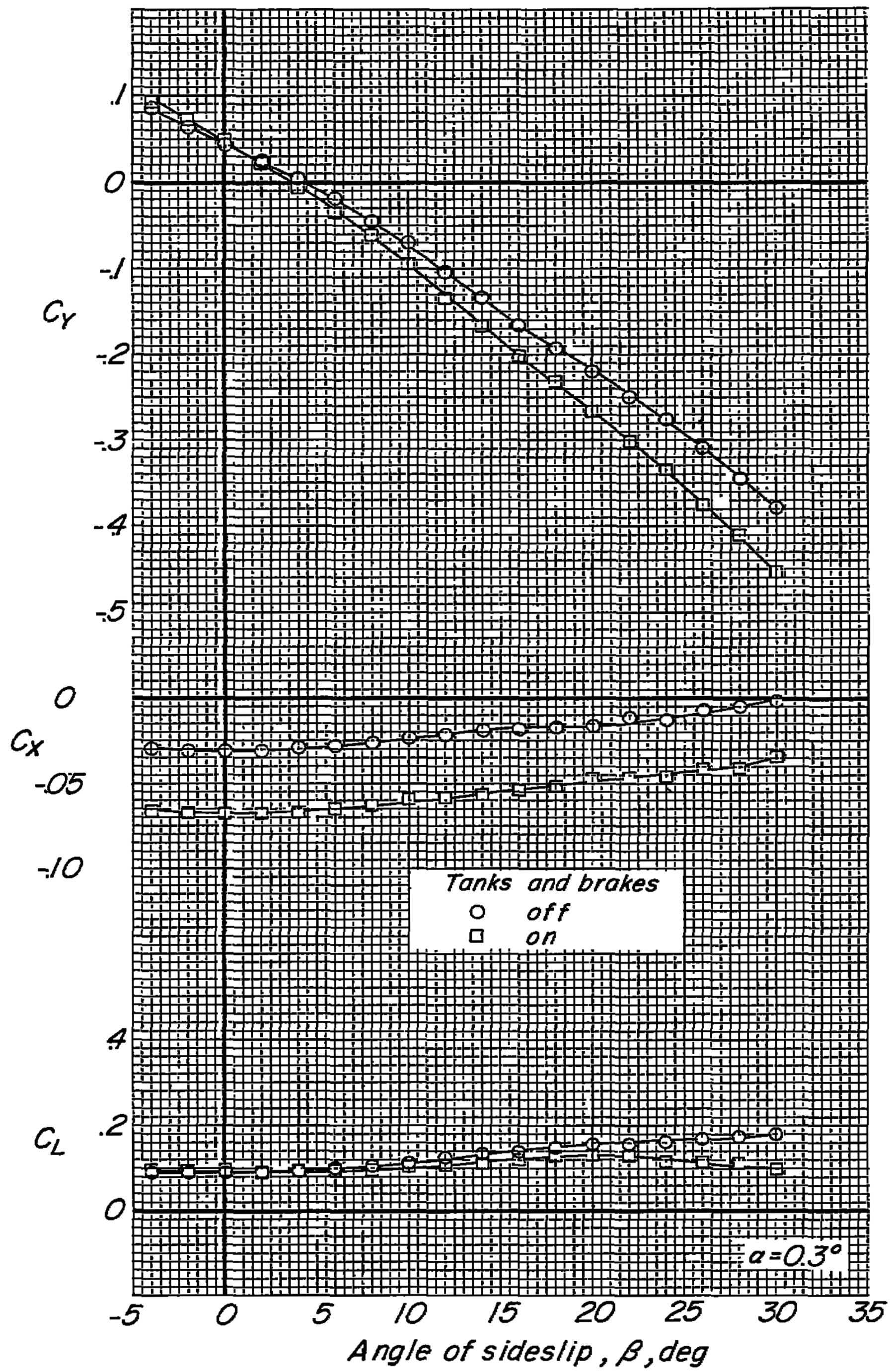


Figure 6.- Concluded.

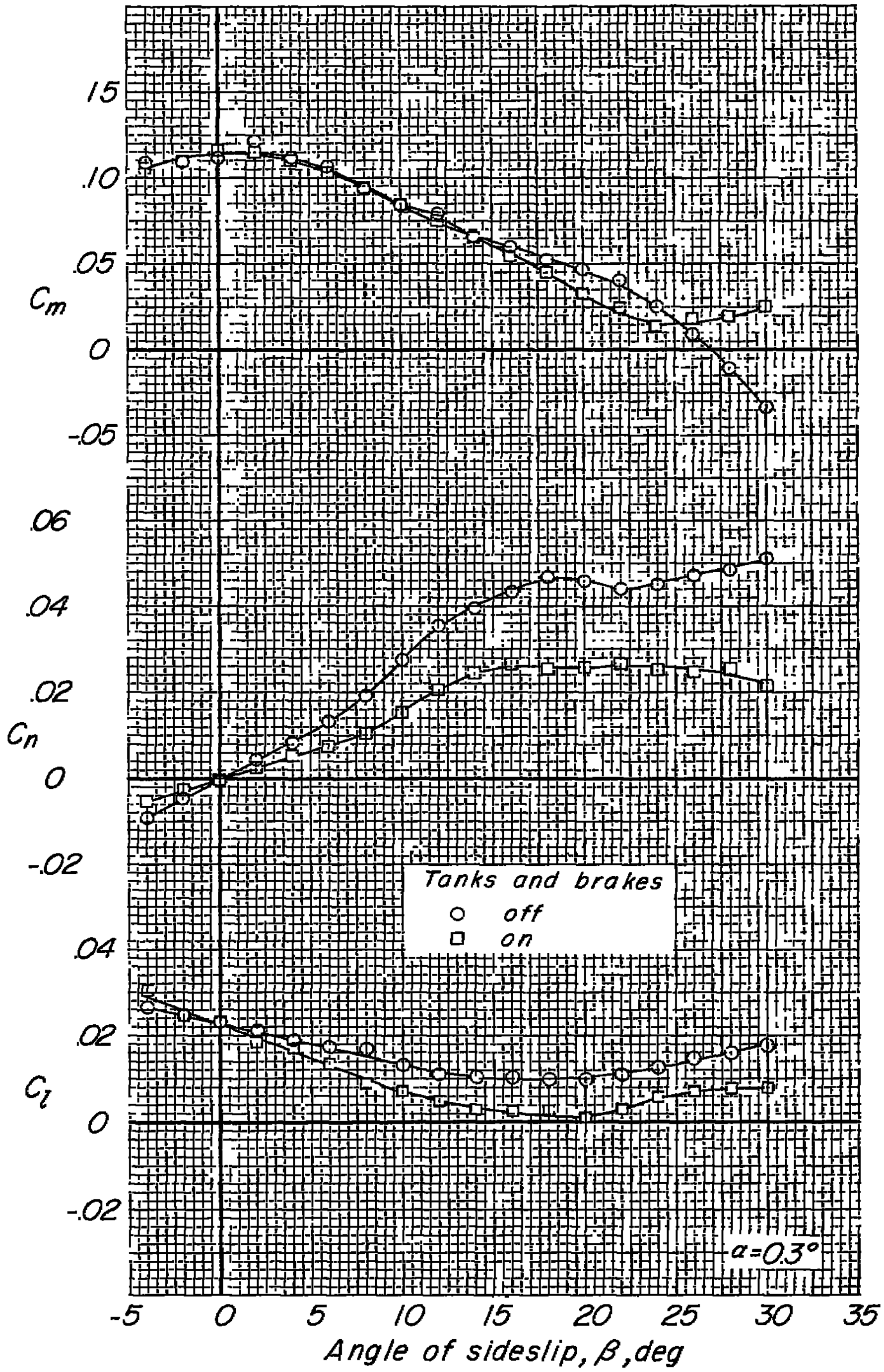


Figure 7.- Effect of tanks and brakes on the aerodynamic characteristics of the model with the ailerons deflected. $\delta_{a_T} = 20^{\circ}$; $\alpha = 0.3^{\circ}$.

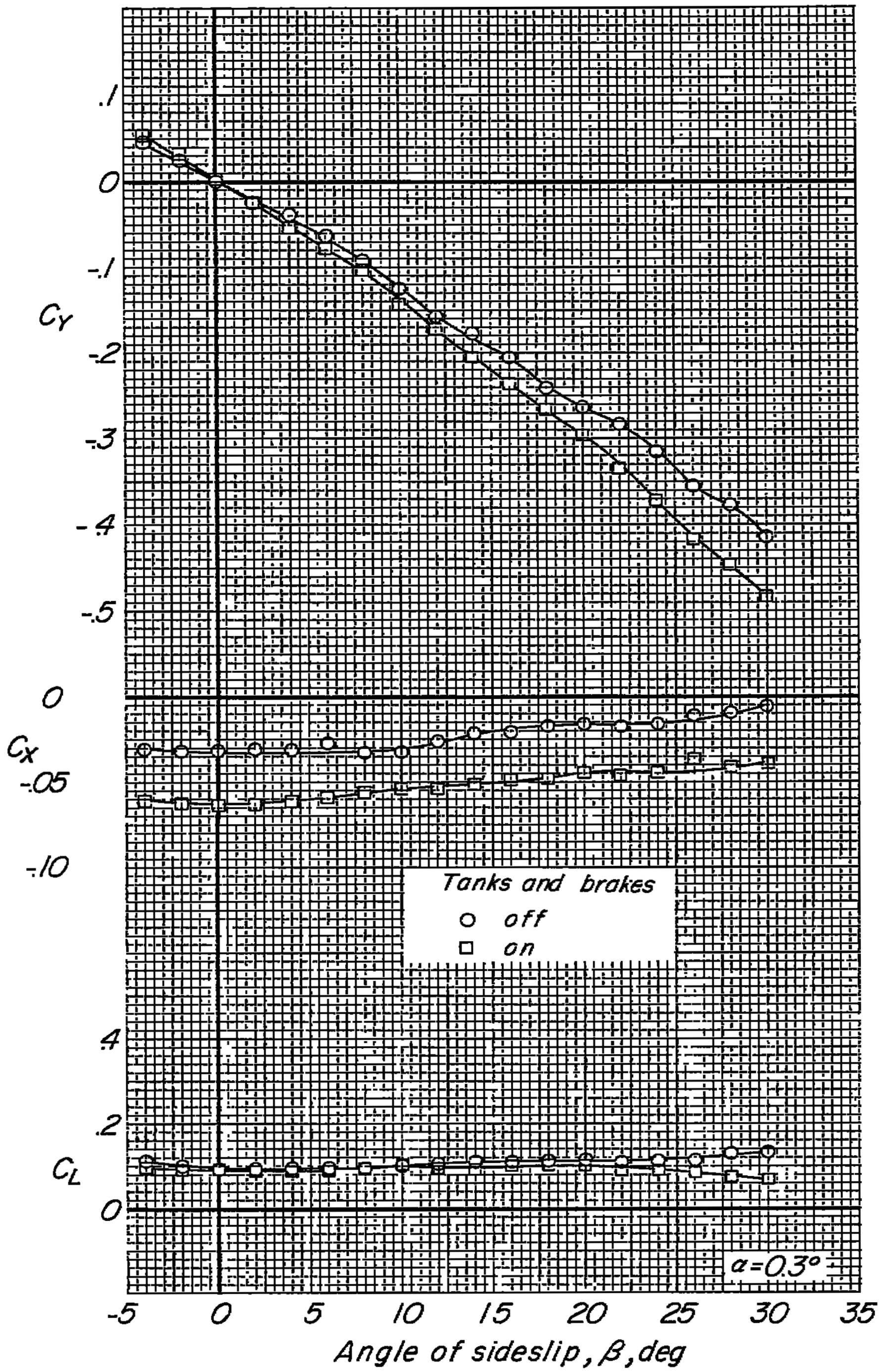


Figure 7.- Concluded.

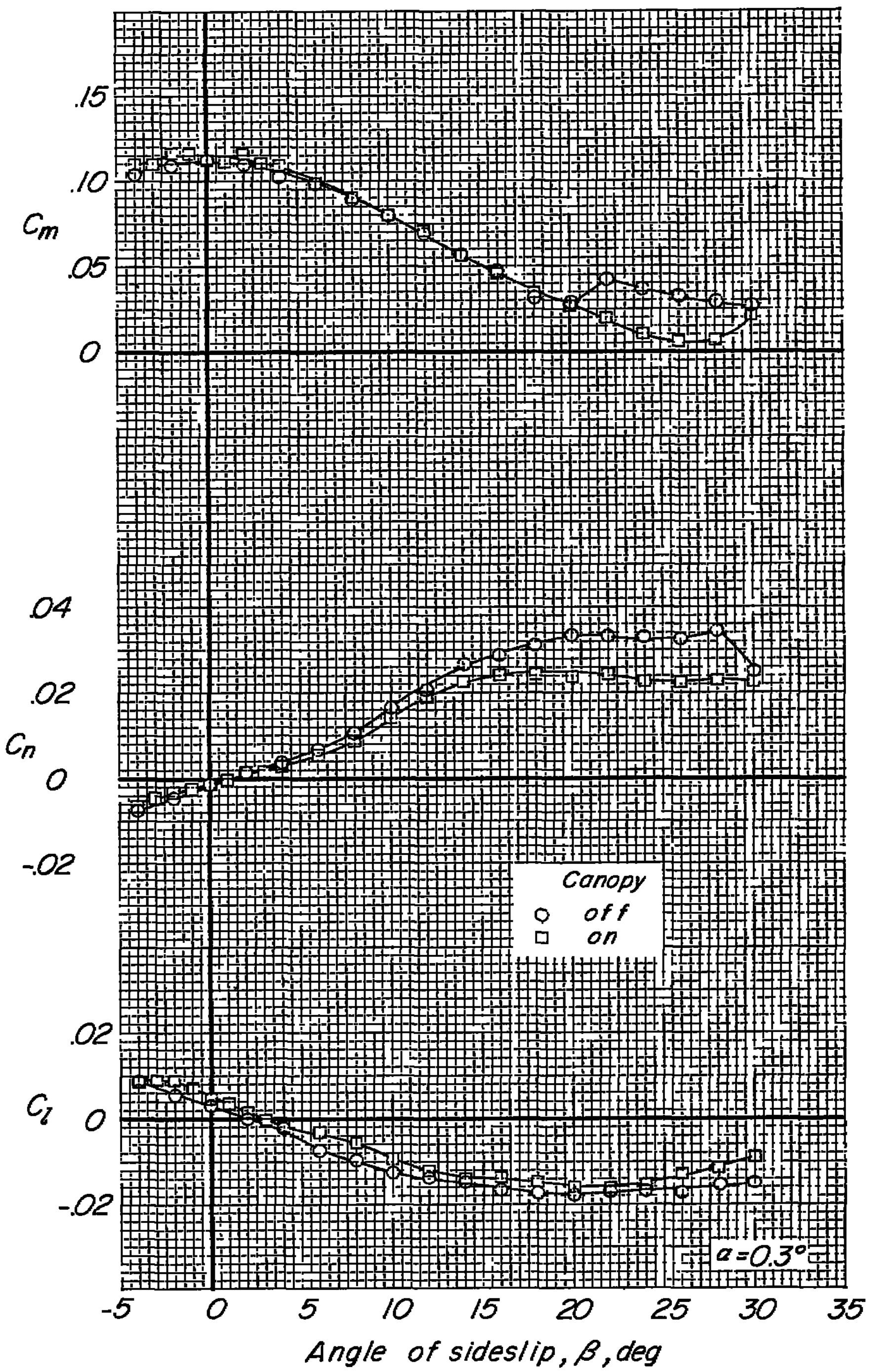


Figure 8.- Effect of the canopy on the aerodynamic characteristics of the model with tanks and brakes installed. $\alpha = 0.3^\circ$.

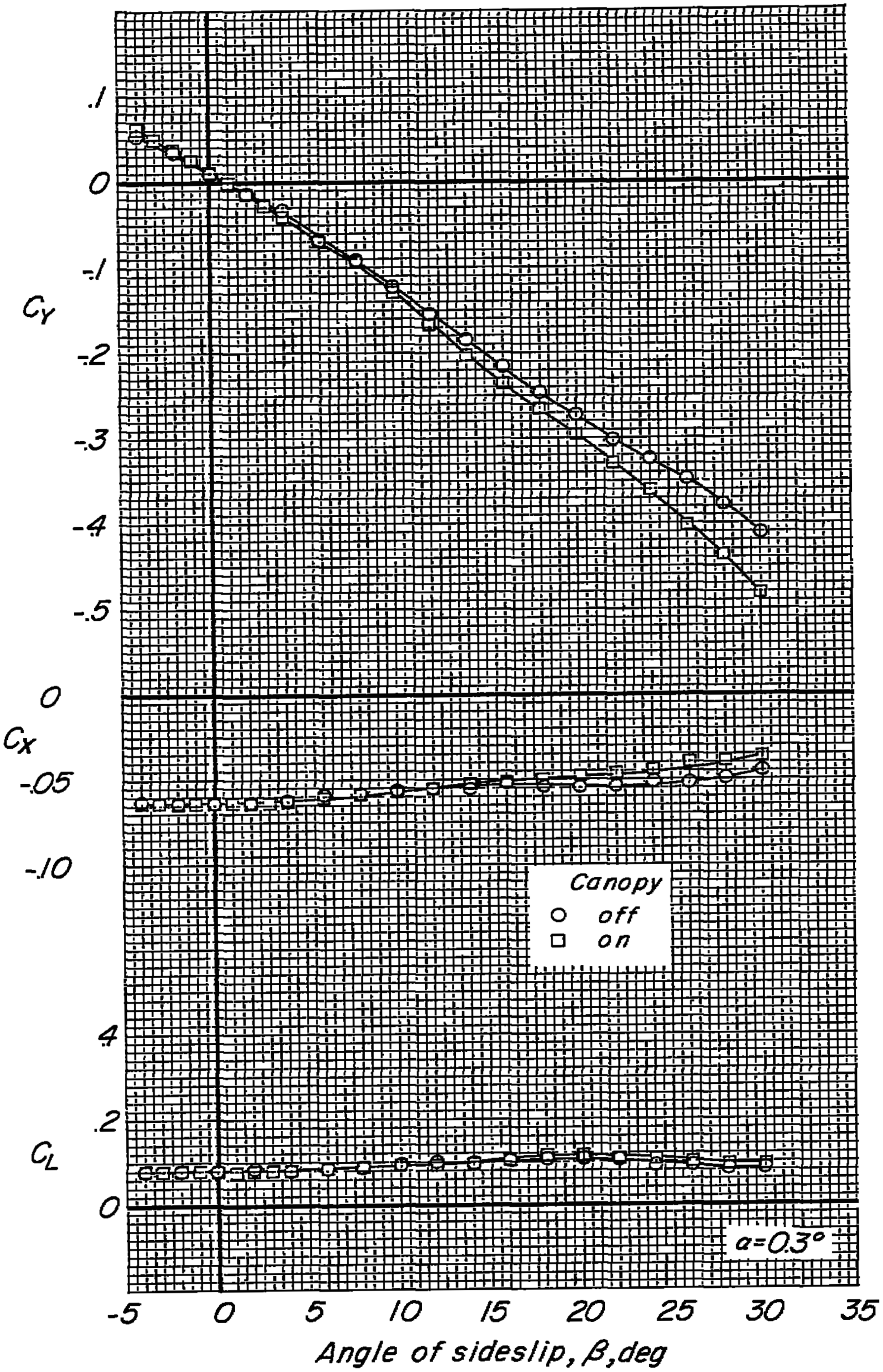


Figure 8.- Concluded.

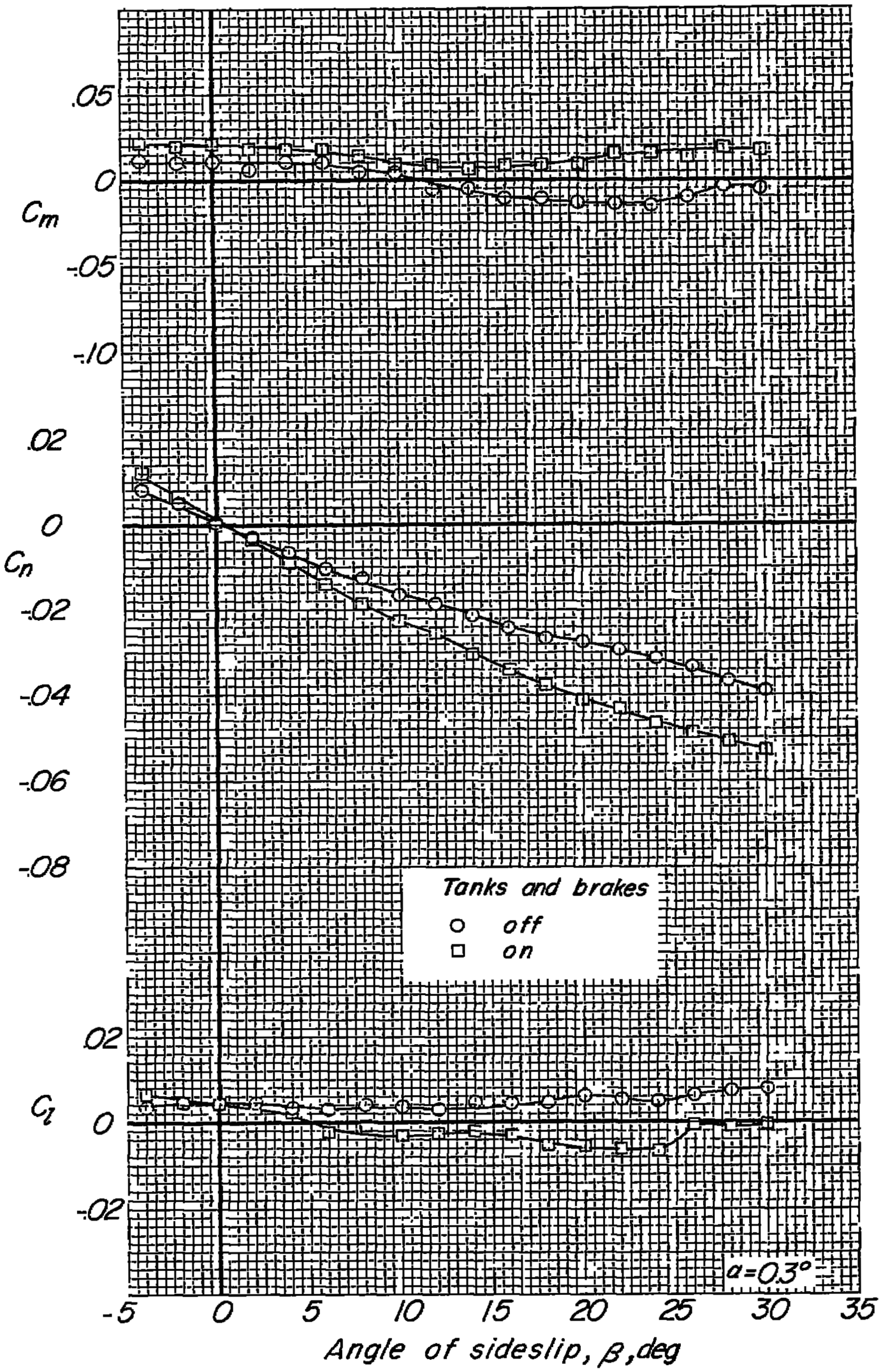


Figure 9.- Effect of tanks and brakes on the aerodynamic characteristics of the model with tail surfaces removed. $\alpha = 0.3^{\circ}$.

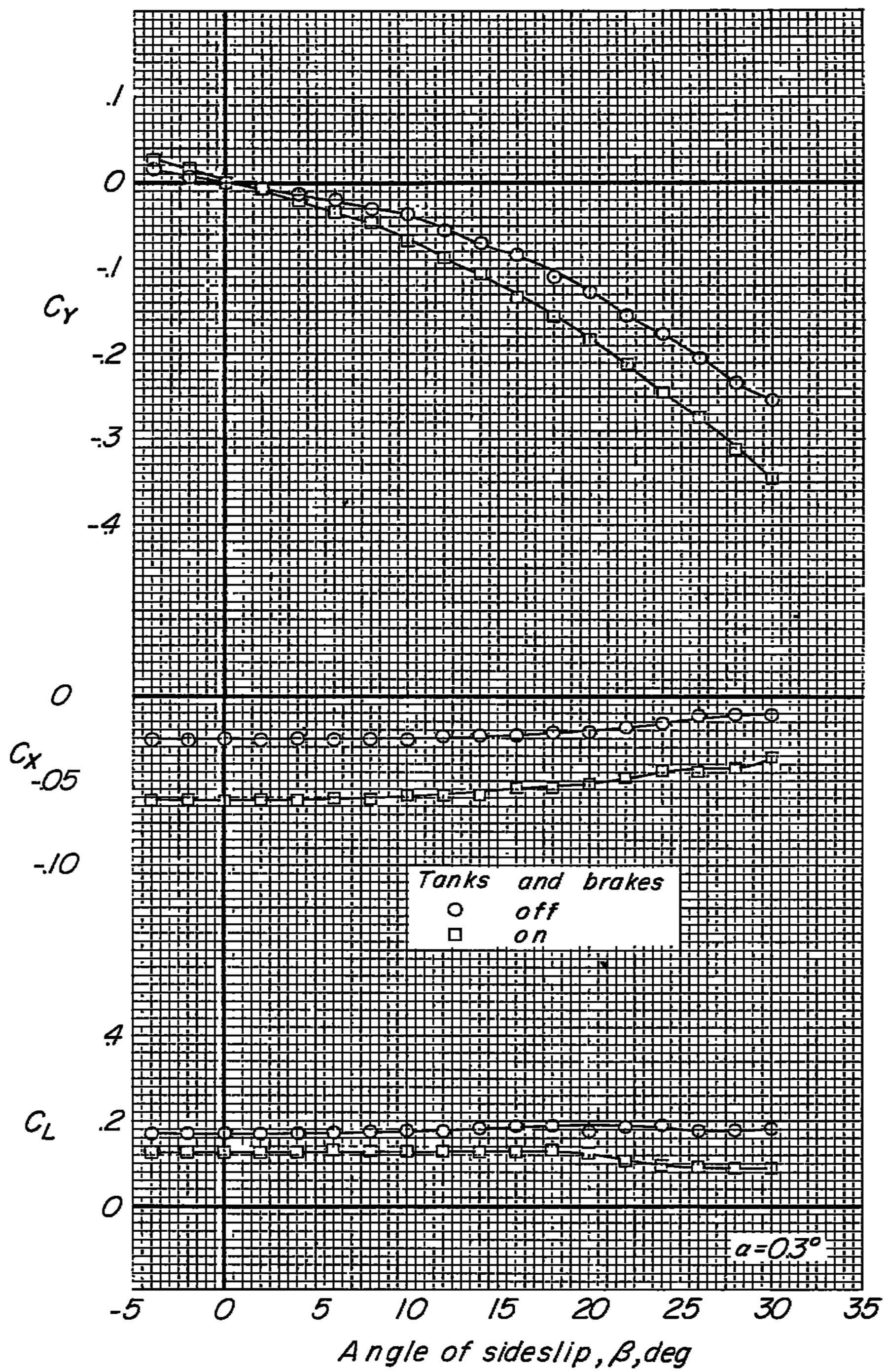


Figure 9.- Concluded.

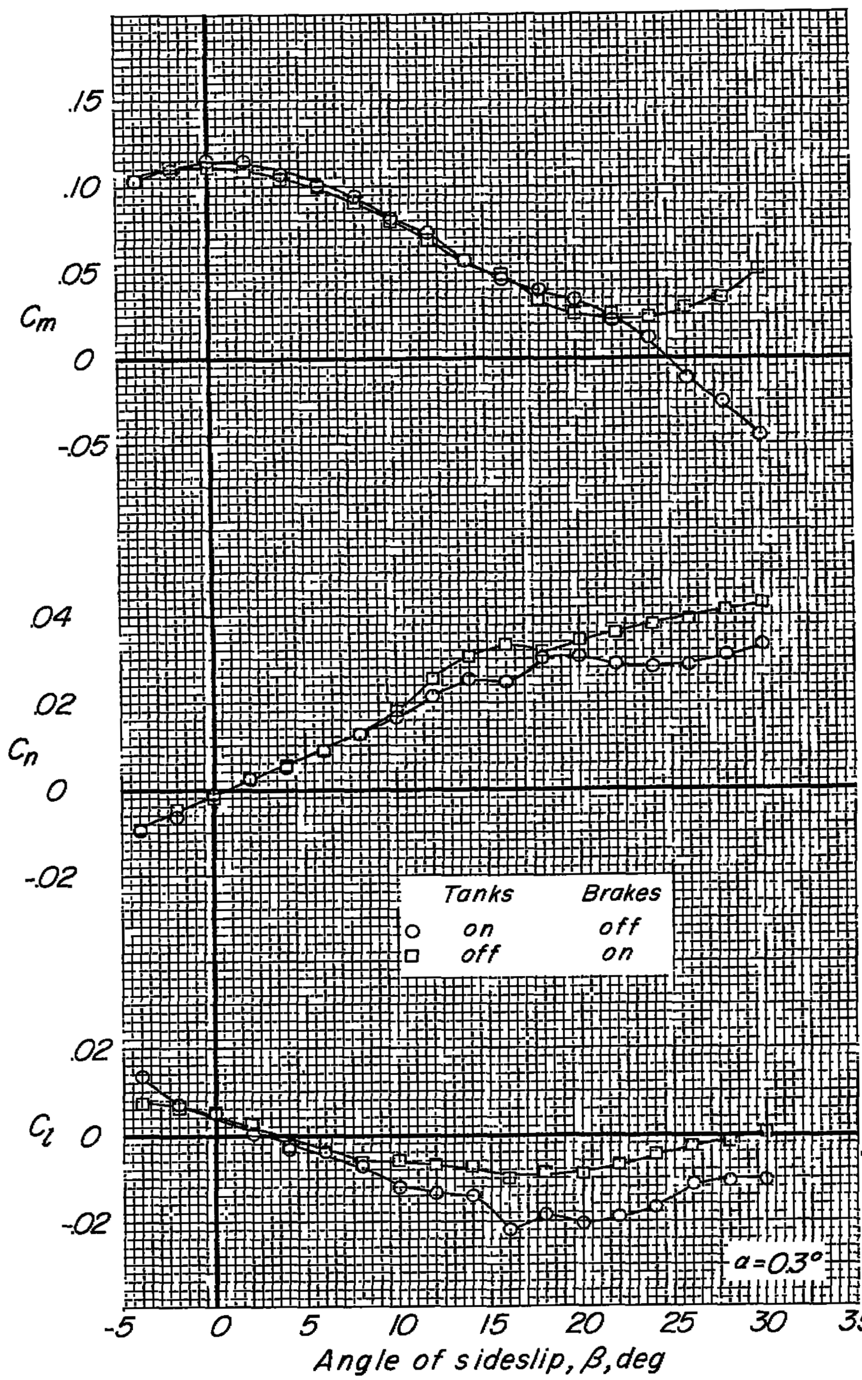


Figure 10.- Aerodynamic characteristics of the model with the tanks and brakes installed separately.

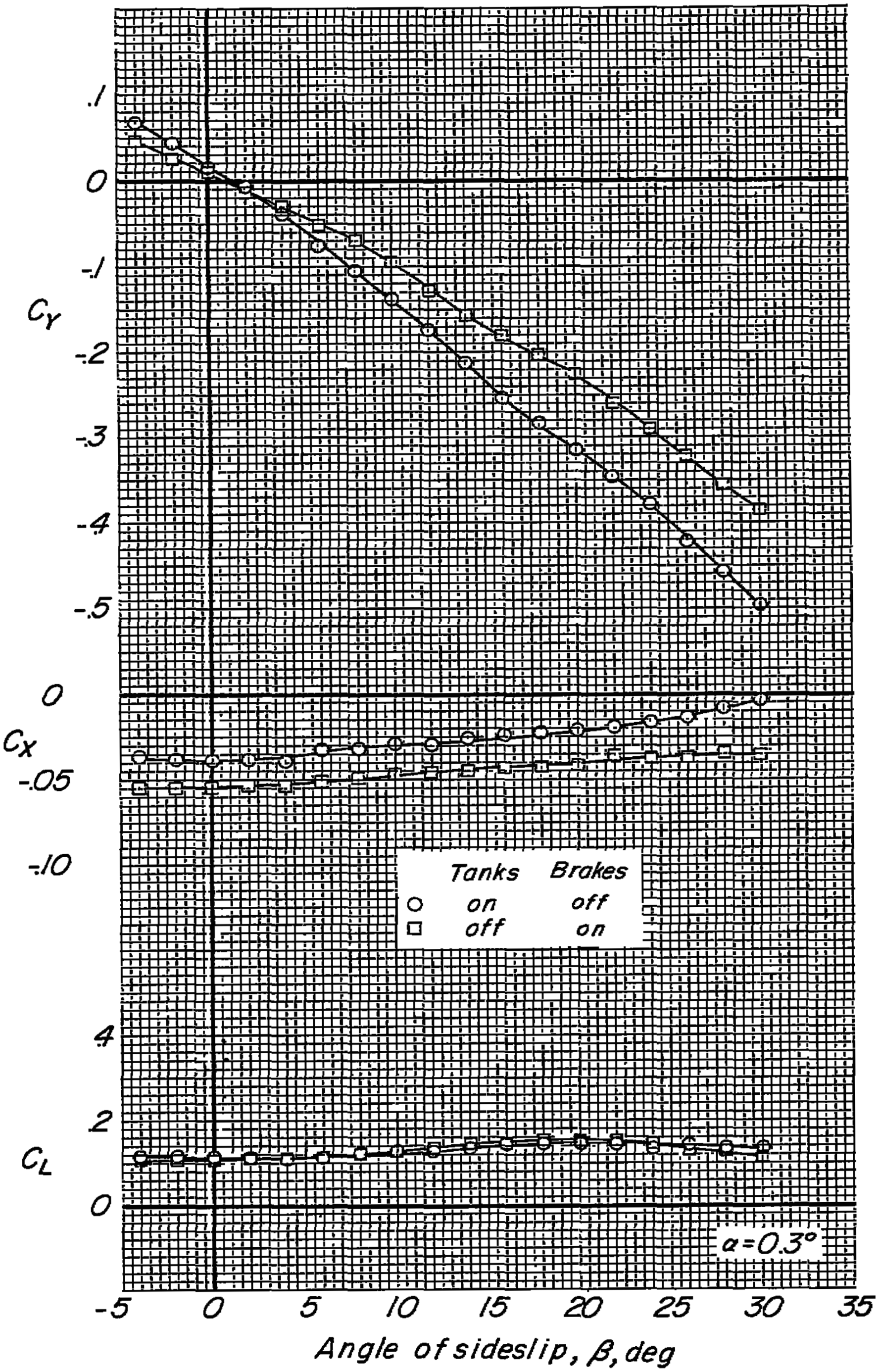


Figure 10.- Concluded.

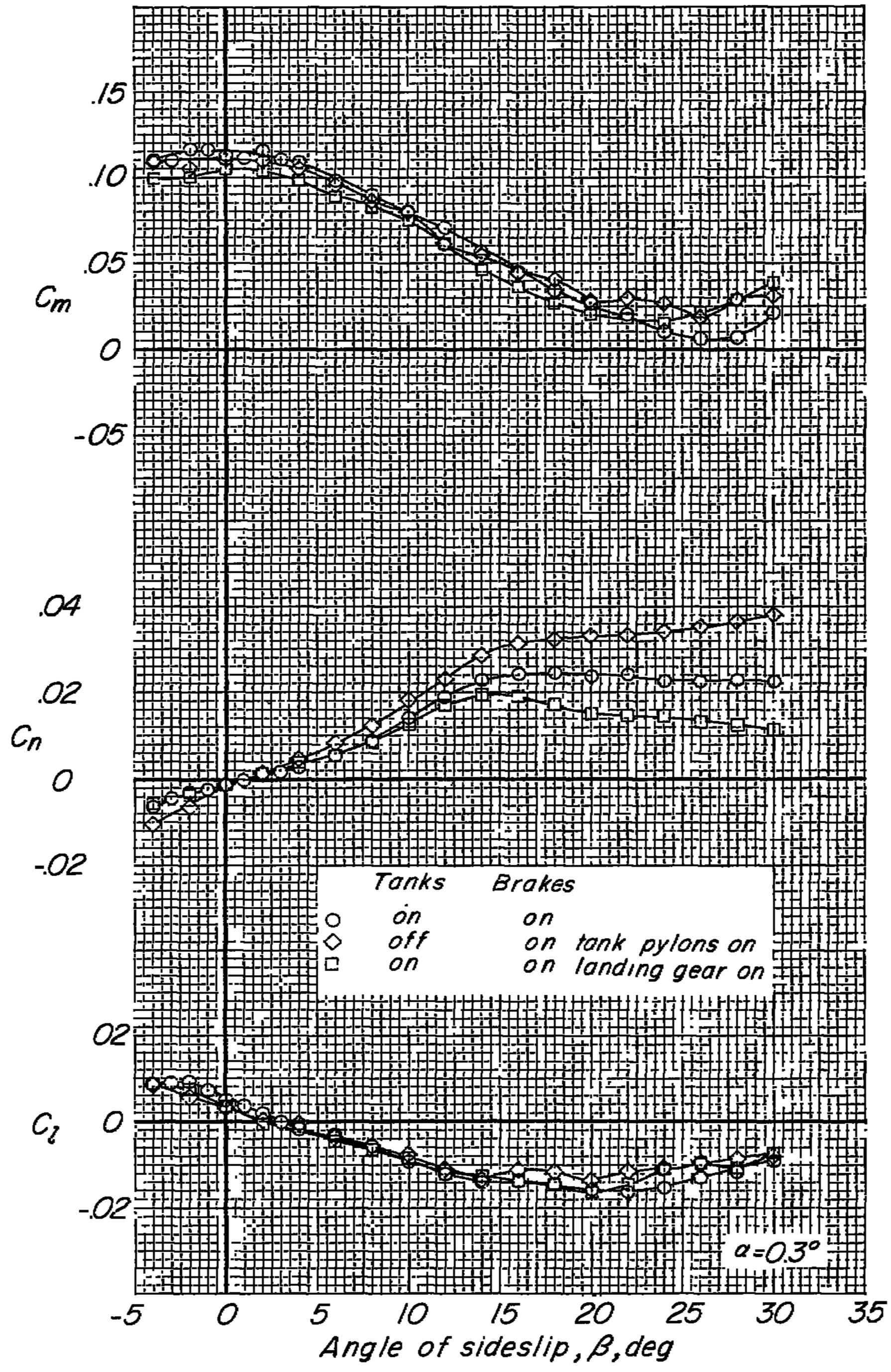


Figure 11.- Effect of tanks, pylons, and landing gear on the aerodynamic characteristics of the model with tanks and brakes installed.

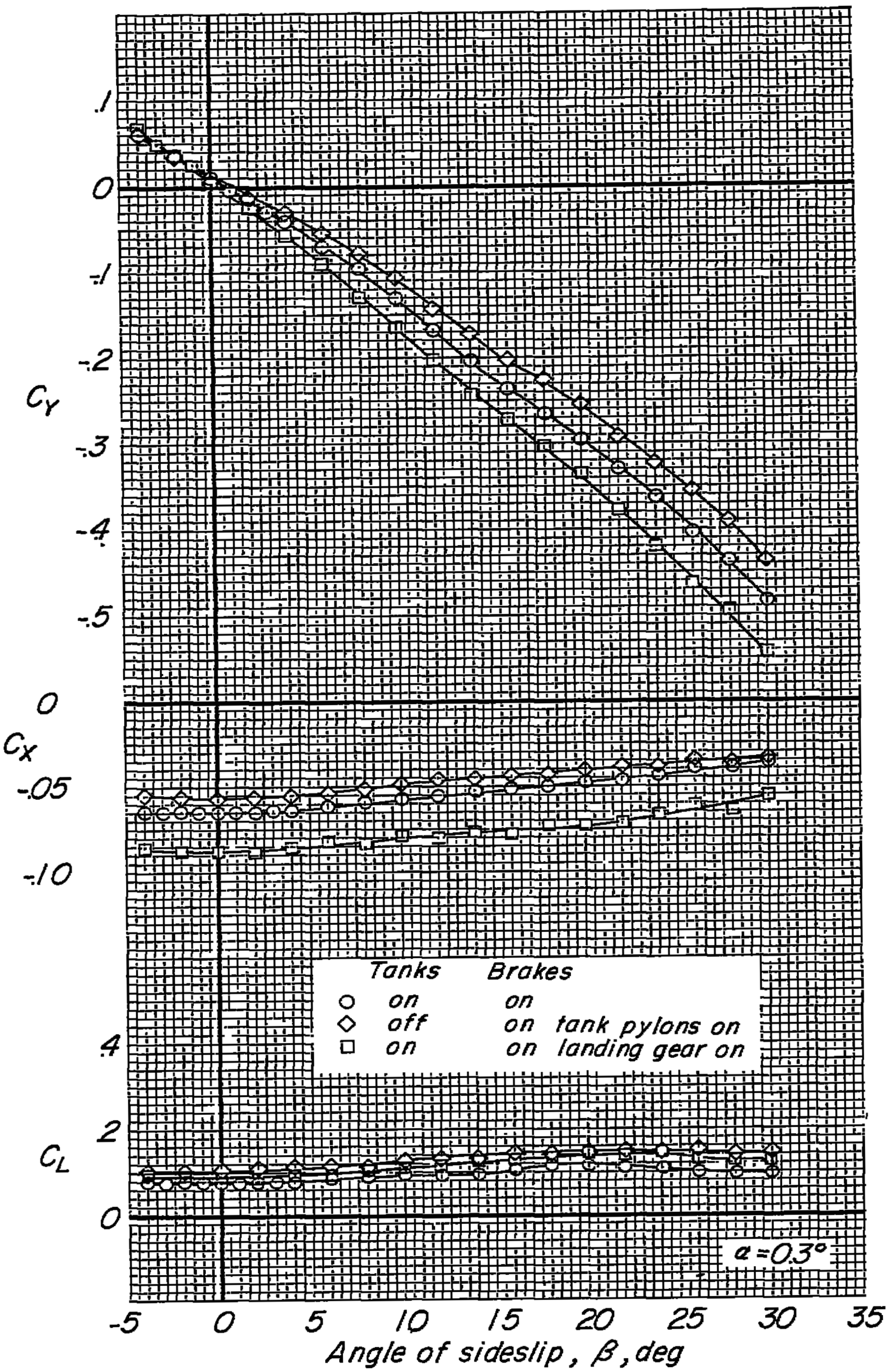
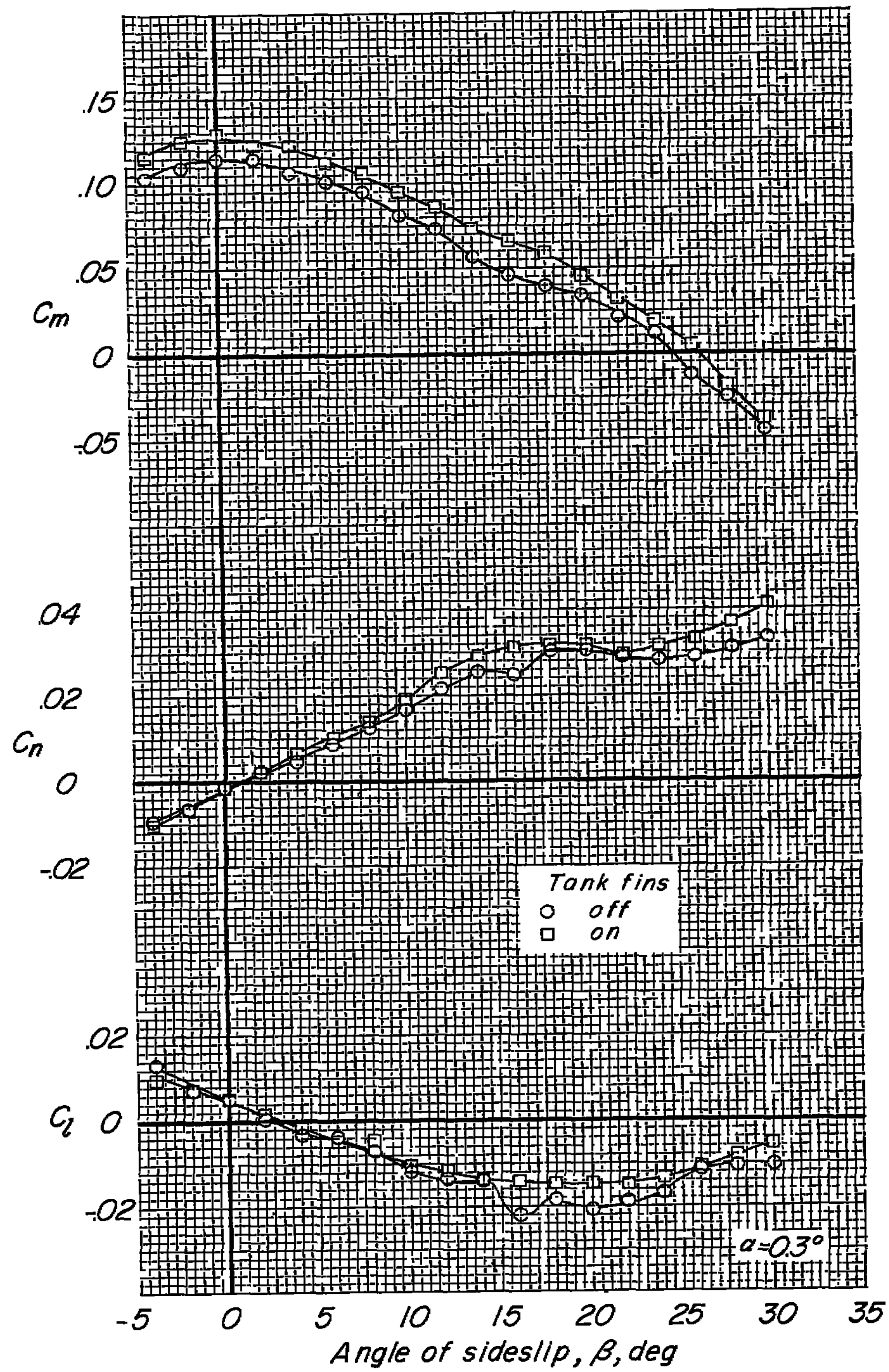
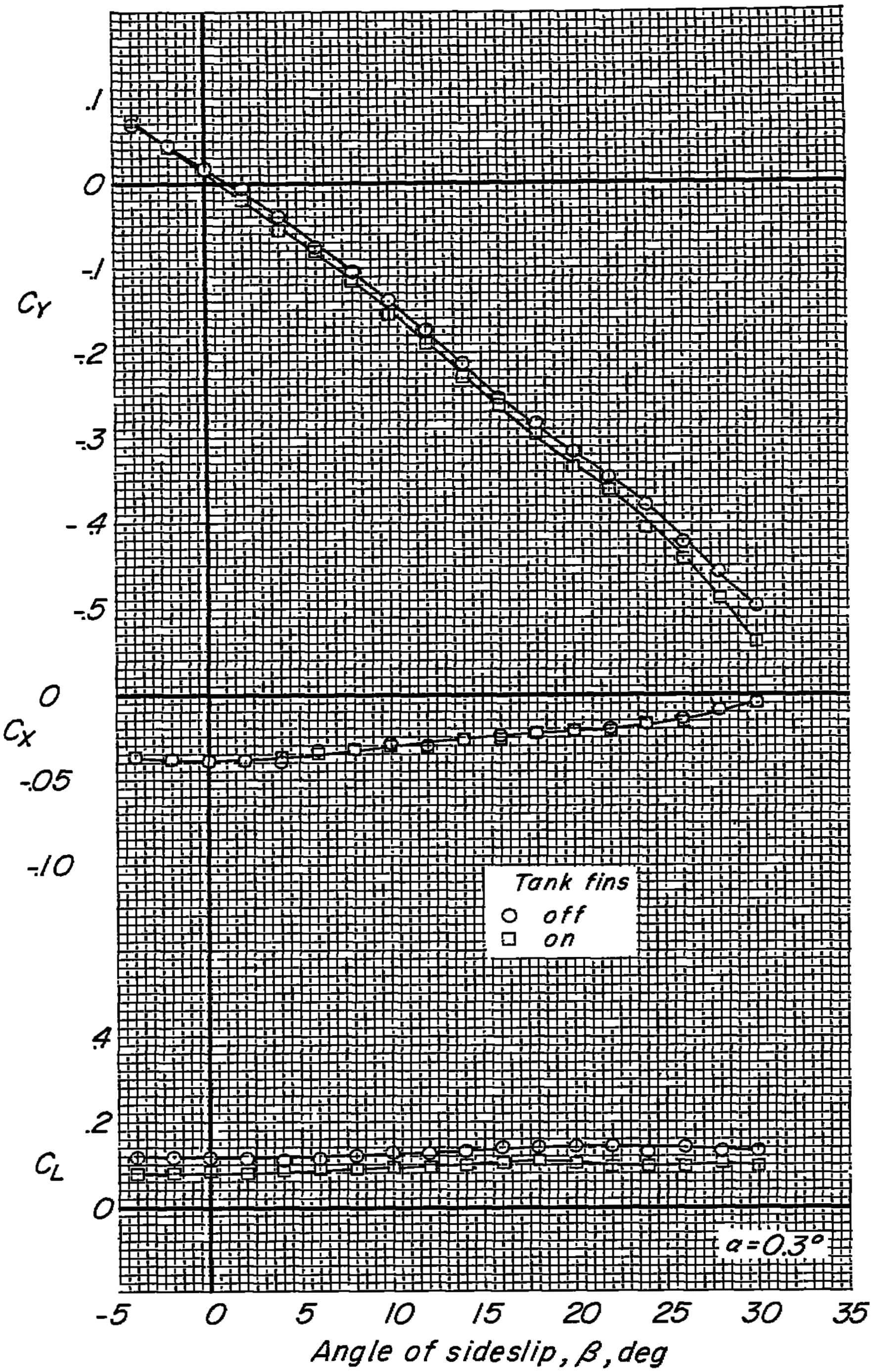


Figure 11.- Concluded.



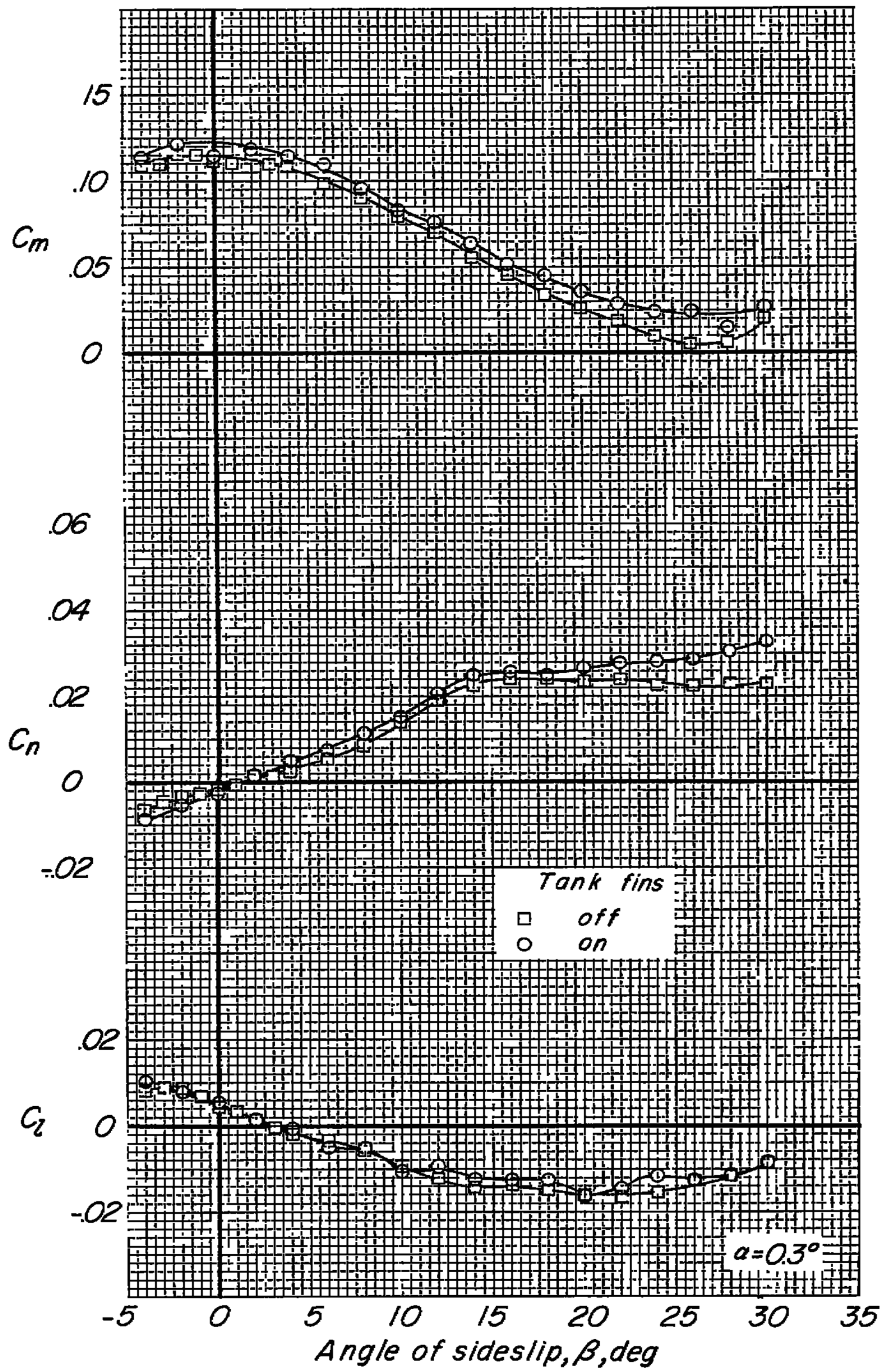
(a) Brakes off.

Figure 12.- Effect of tank fins on the aerodynamic characteristics of the model with tanks installed.



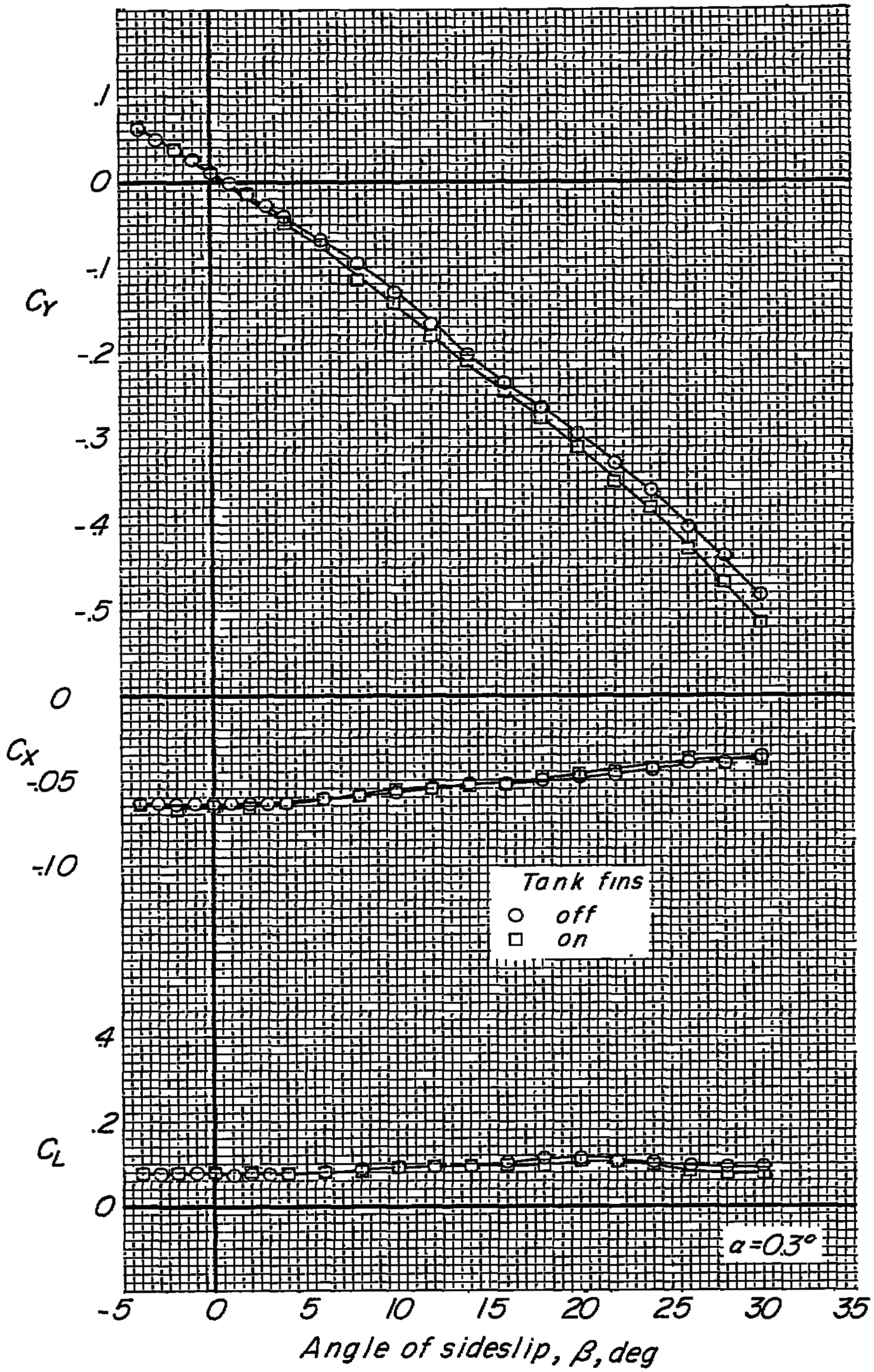
(a) Concluded.

Figure 12.- Continued.



(b) Brakes on.

Figure 12.- Continued.



(b) Concluded.

Figure 12.- Concluded.

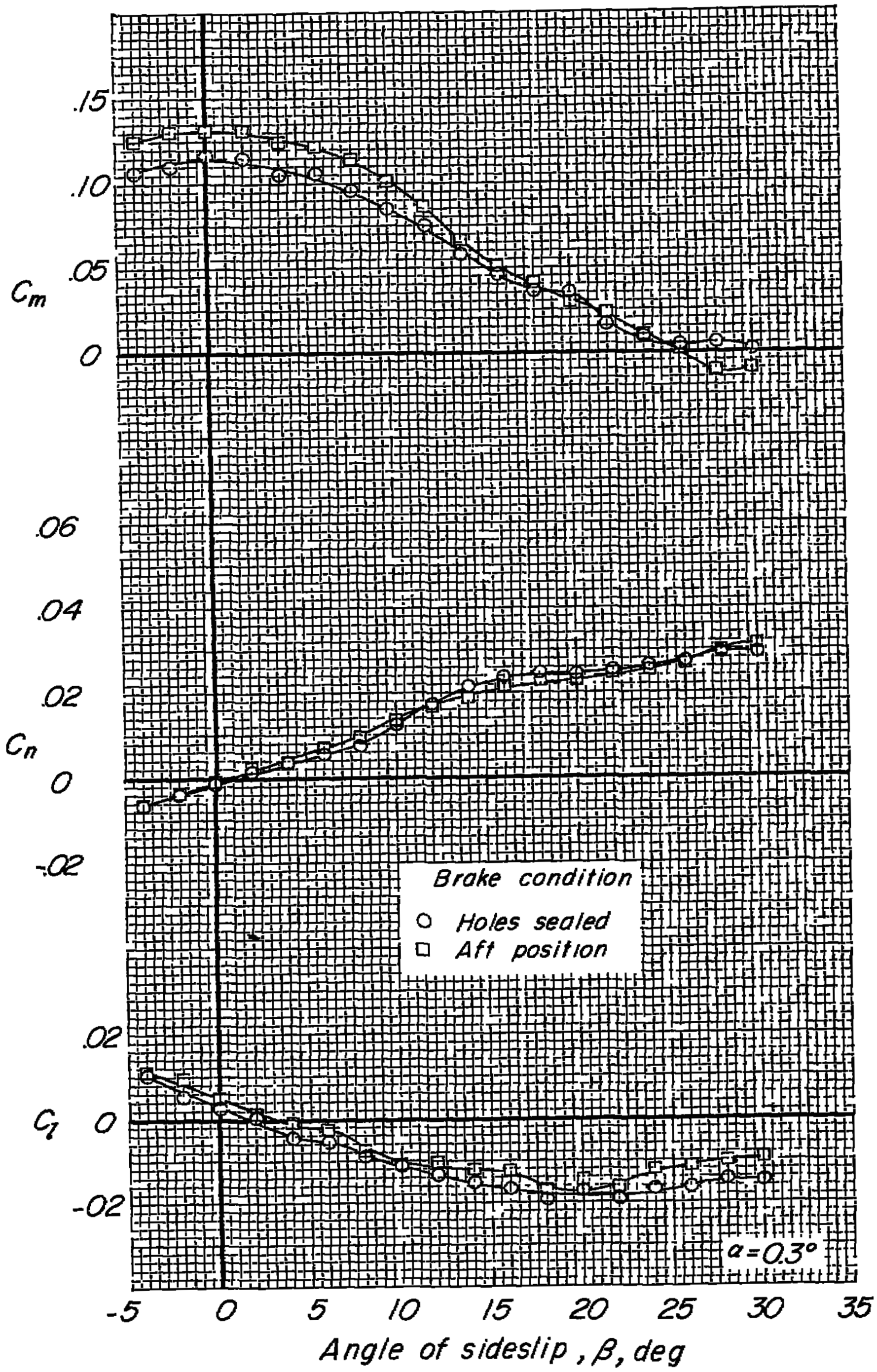


Figure 13.- Aerodynamic characteristics of the model with the speed brakes modified and tanks installed.

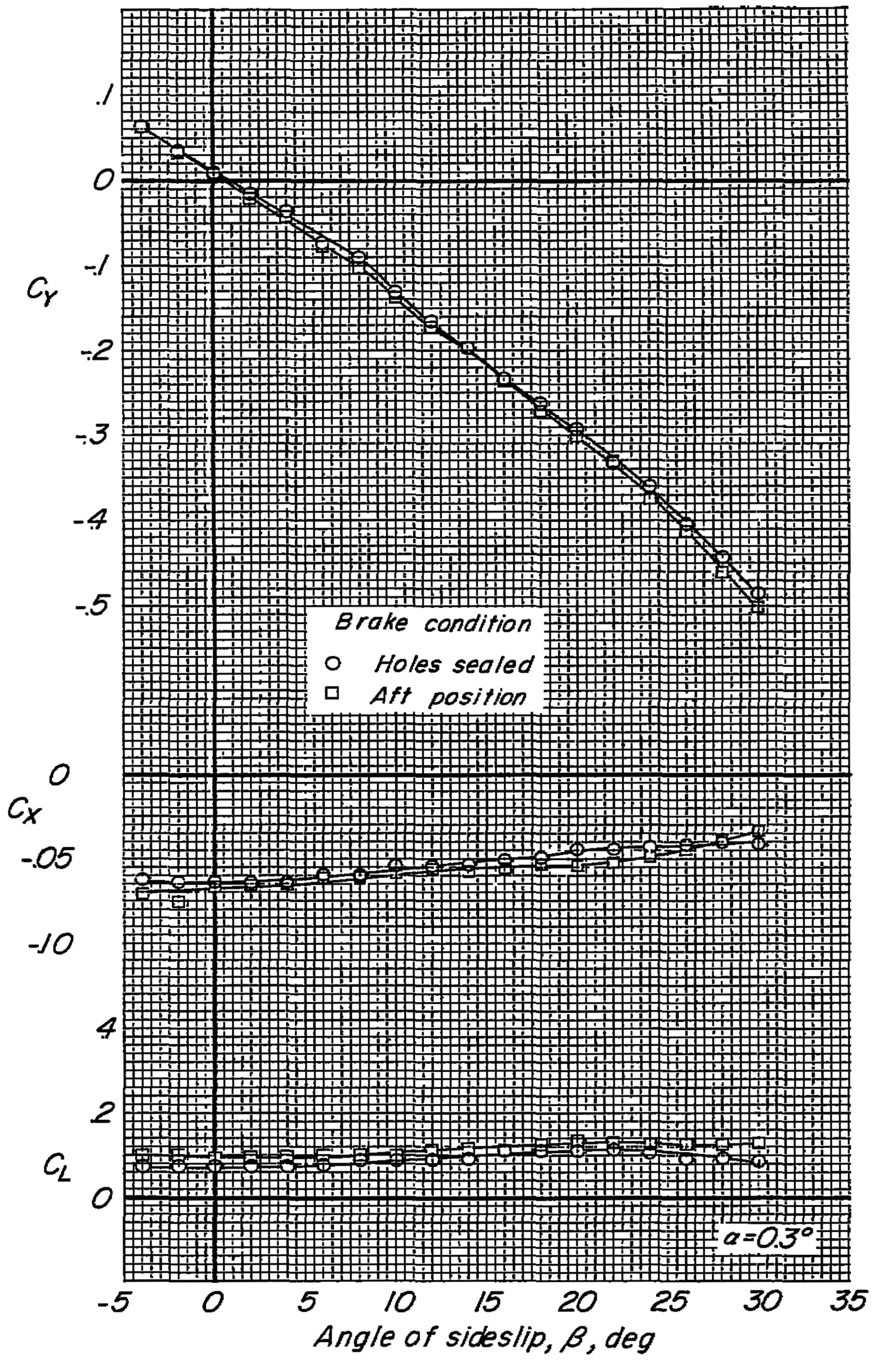


Figure 13.- Concluded.

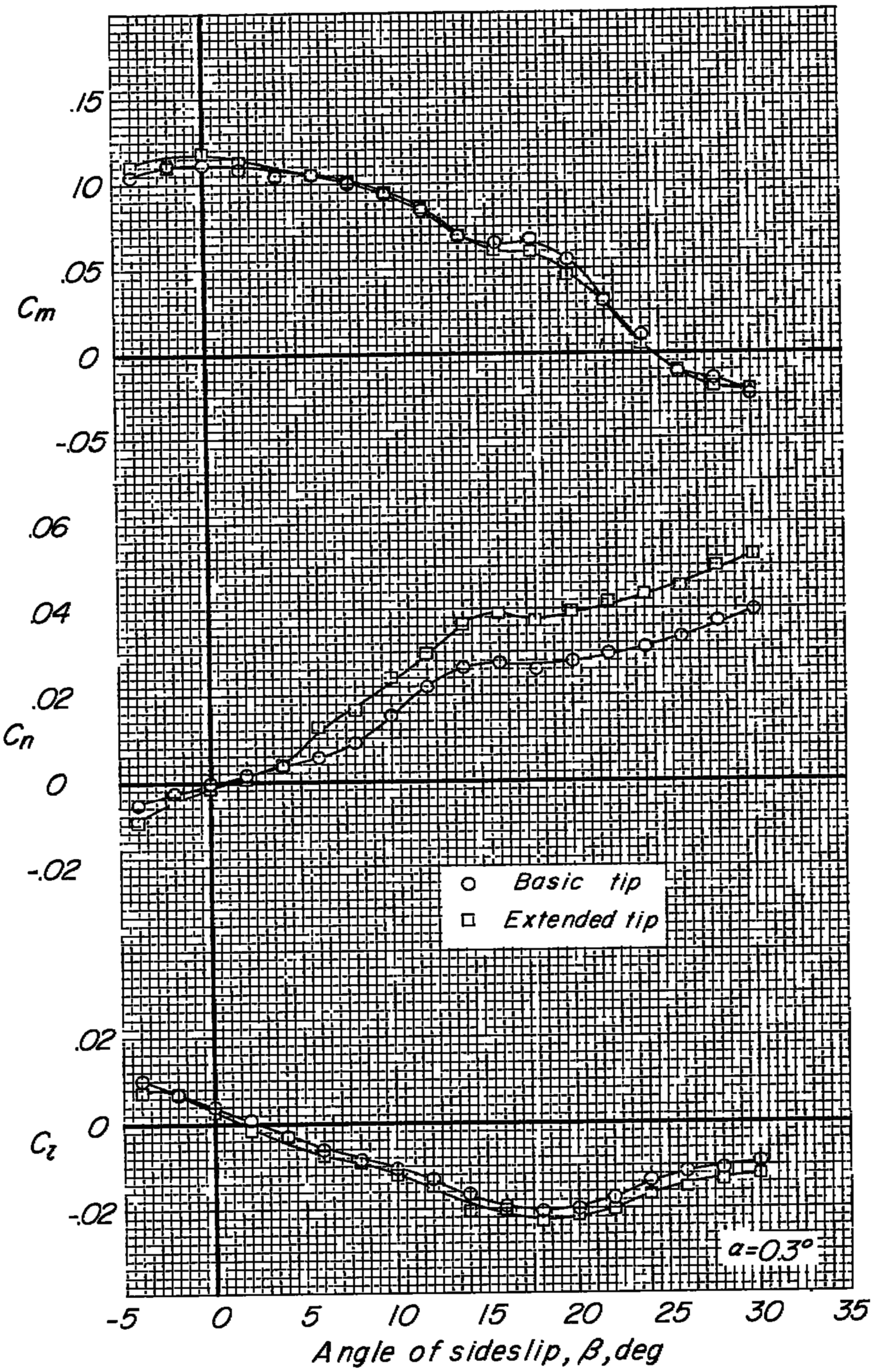


Figure 14.- Effect of the vertical-tail extension on the aerodynamic characteristics of the model with tanks and brakes installed and large dorsal fin.

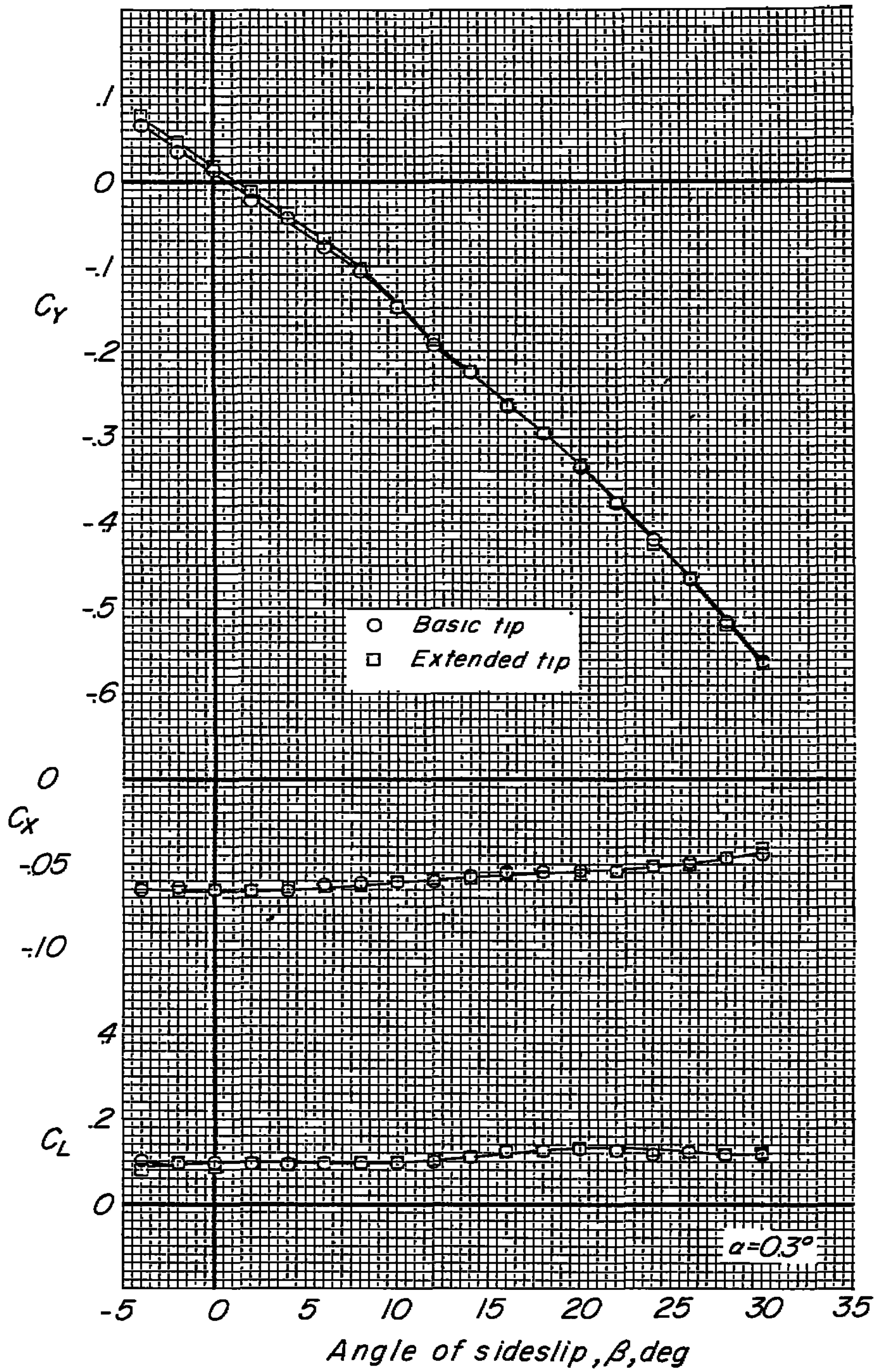


Figure 14.- Concluded.

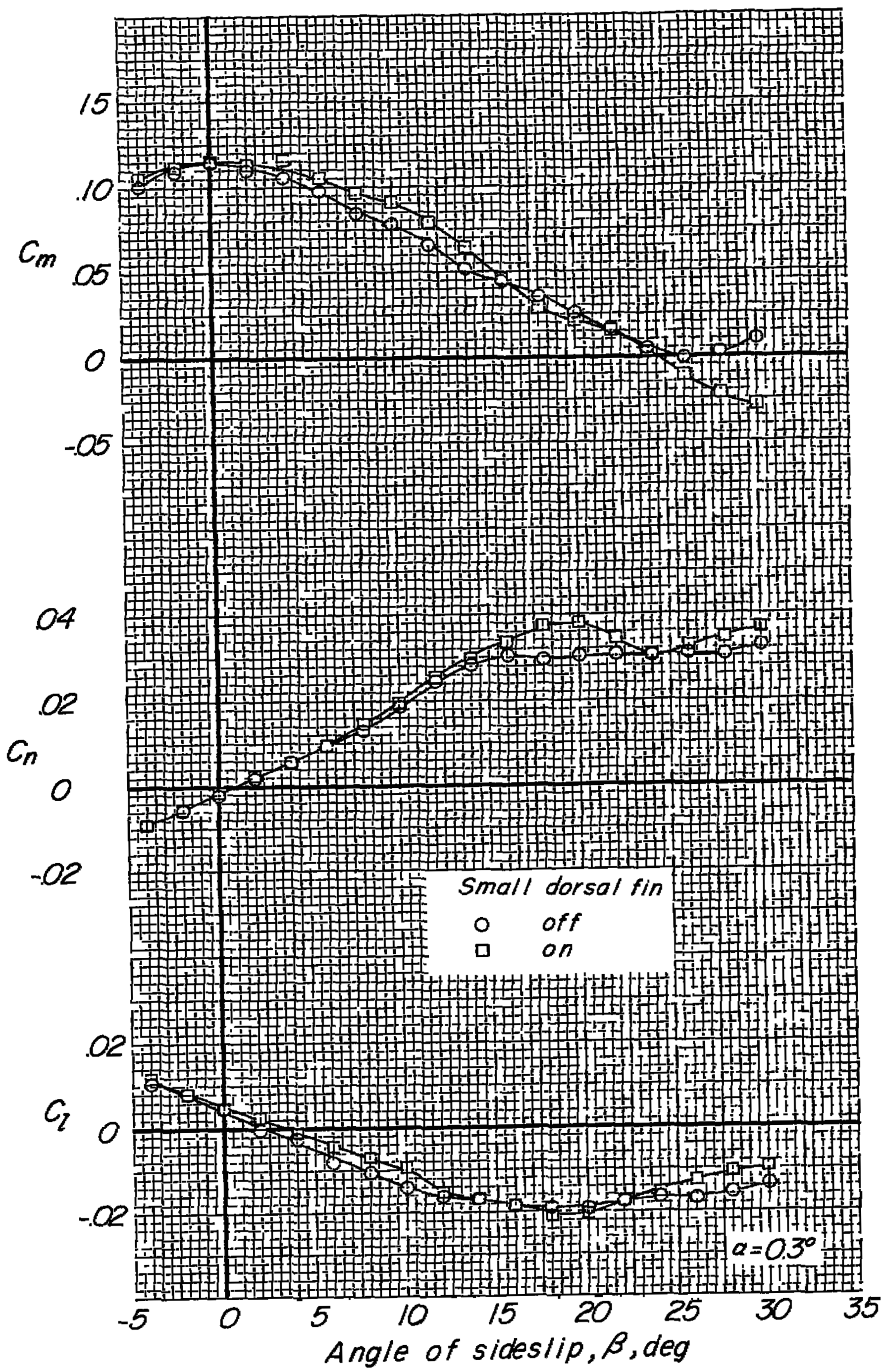


Figure 15.- Effect of the small dorsal fin on the aerodynamic characteristics of the model with tanks and brakes installed and extended vertical tail.

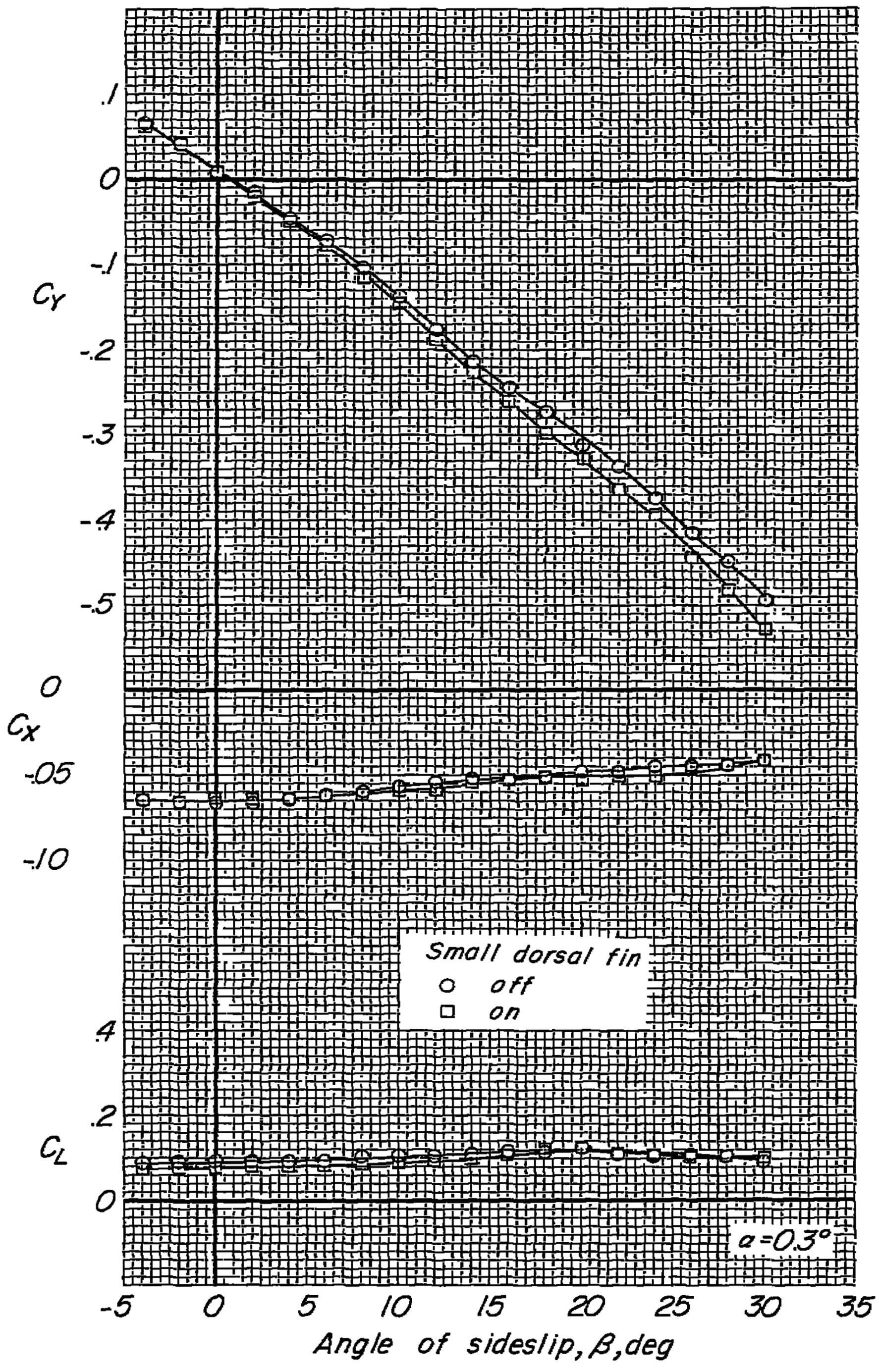


Figure 15.- Concluded.

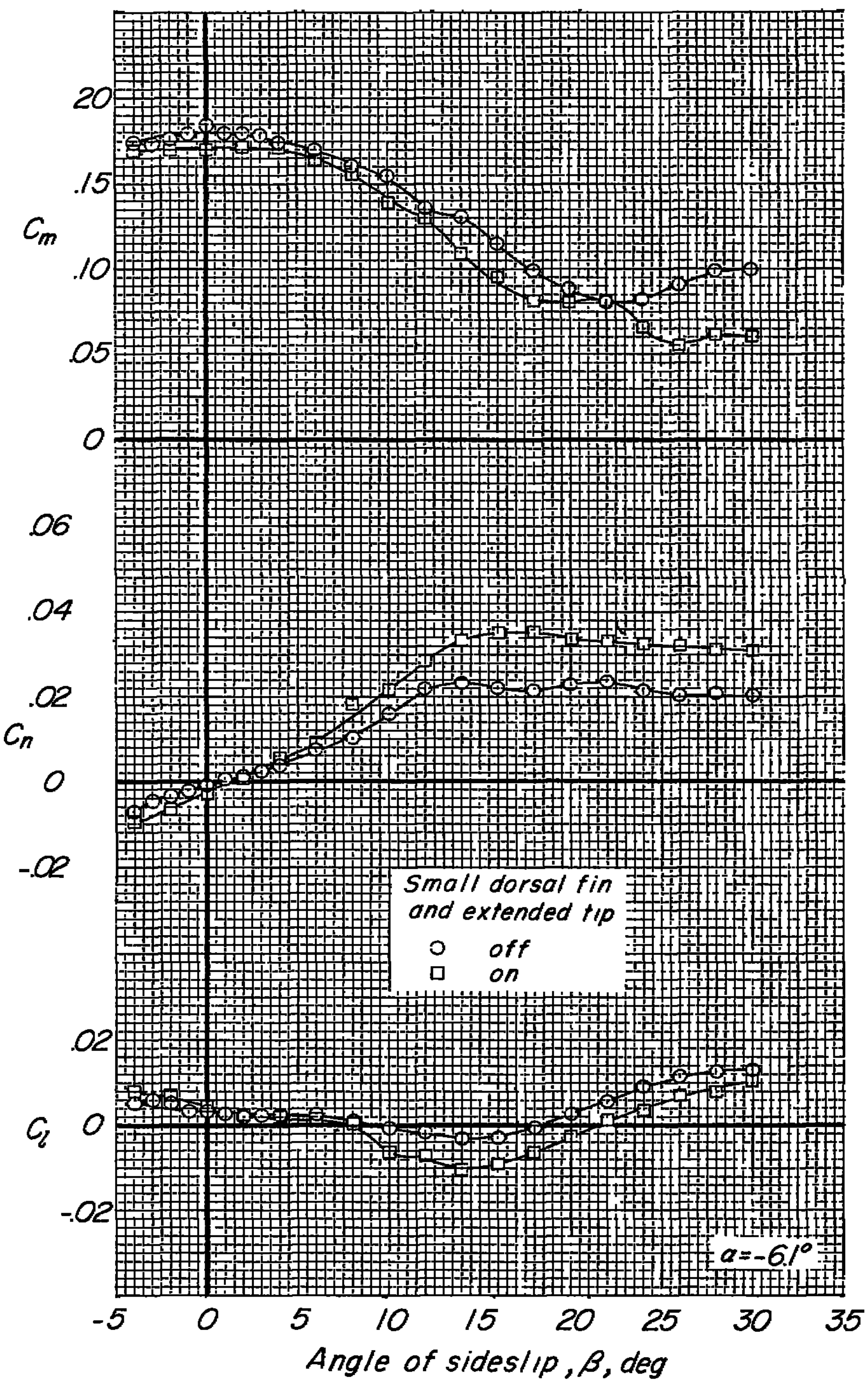


Figure 16.- Combined effect of the small dorsal fin and extended vertical tail on the aerodynamic characteristics of the model with tanks and brakes installed.

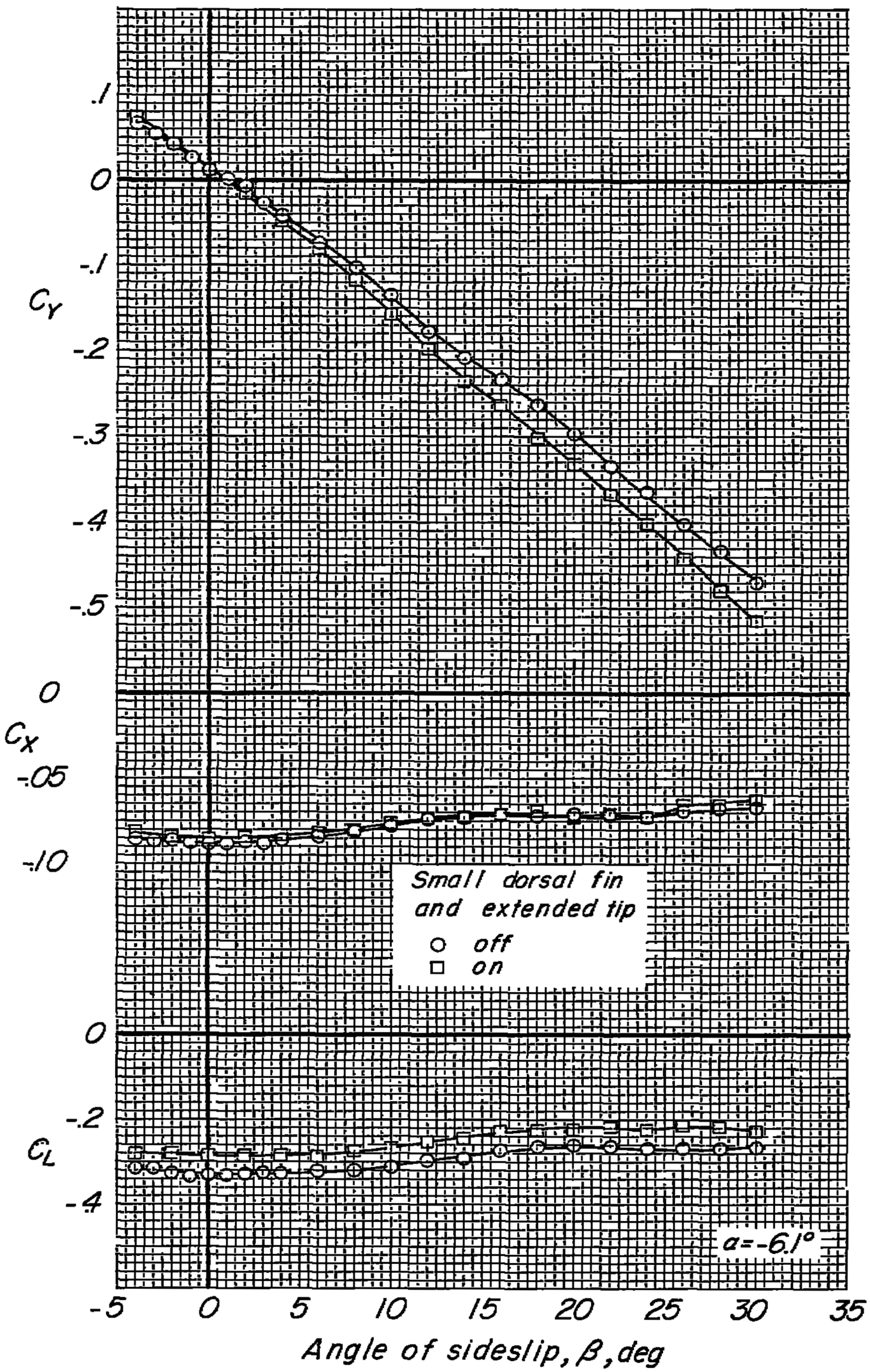


Figure 16.- Concluded.

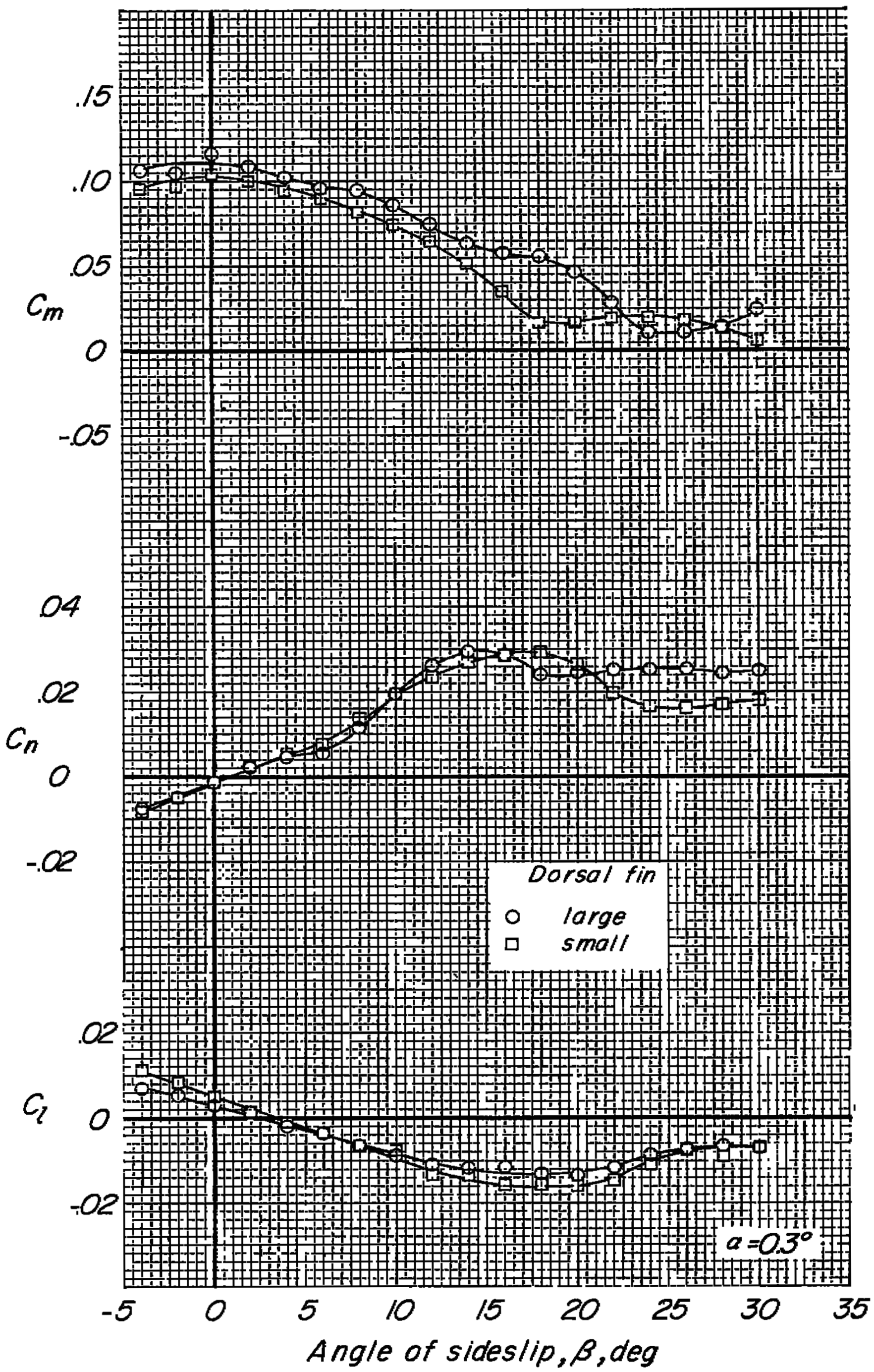


Figure 17.- Effect of dorsal fin size on the aerodynamic characteristics of the model with tanks and brakes installed, extended vertical tail, and landing gear.

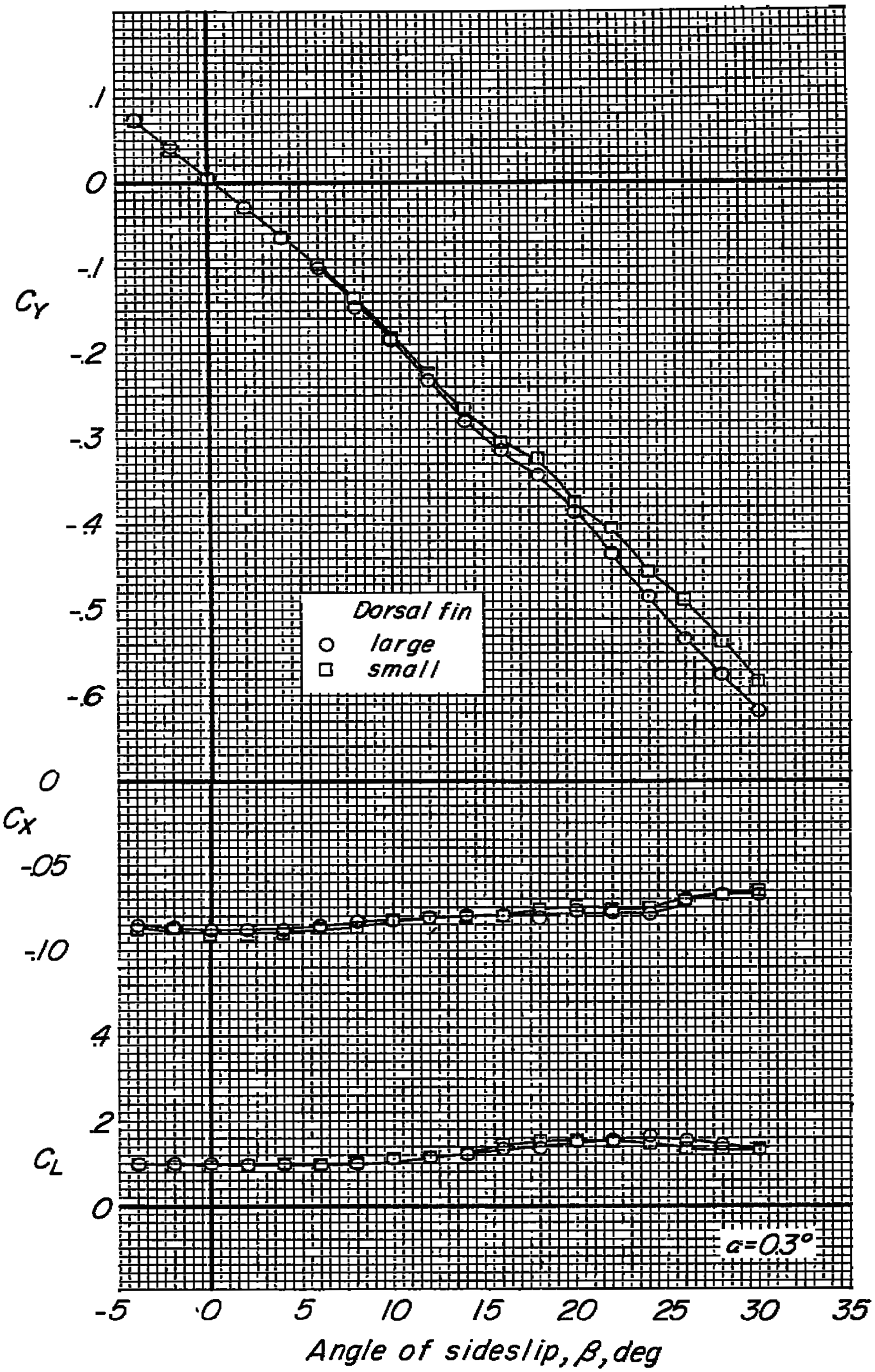


Figure 17.- Concluded.

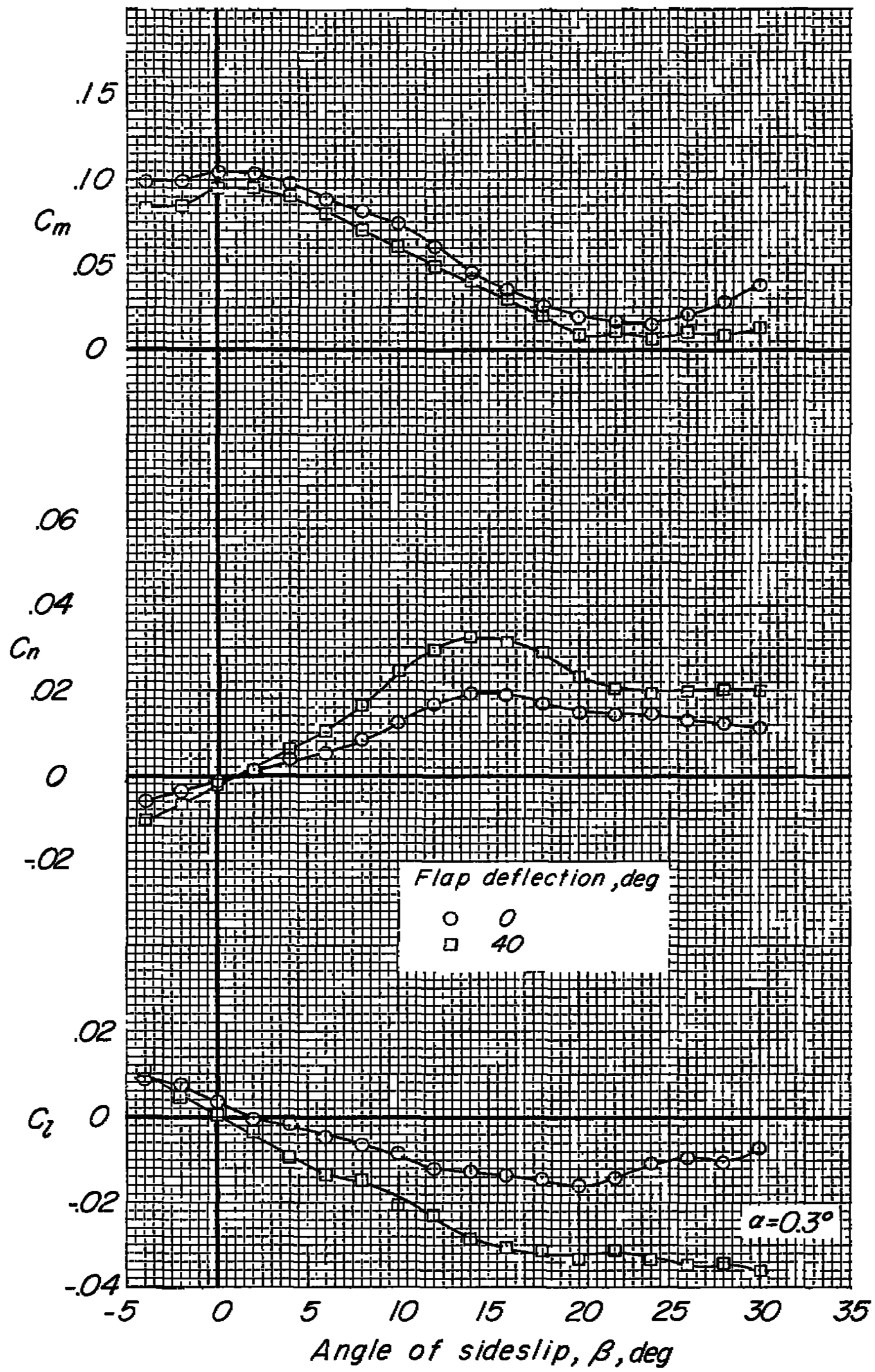


Figure 18.- Effect of flap deflection on the aerodynamic characteristics of the model with tanks and brakes installed and landing gear on.

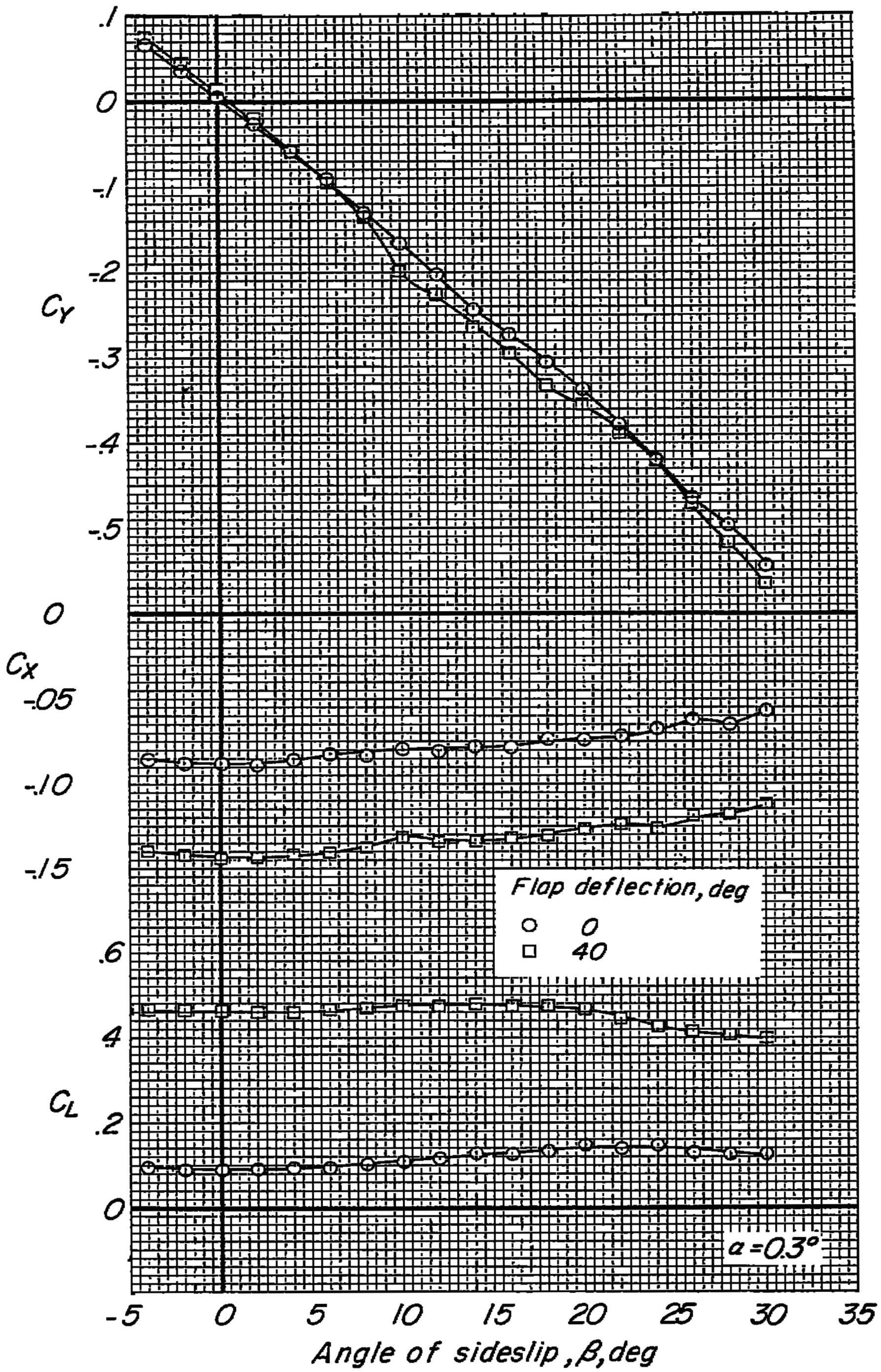


Figure 18.- Concluded.

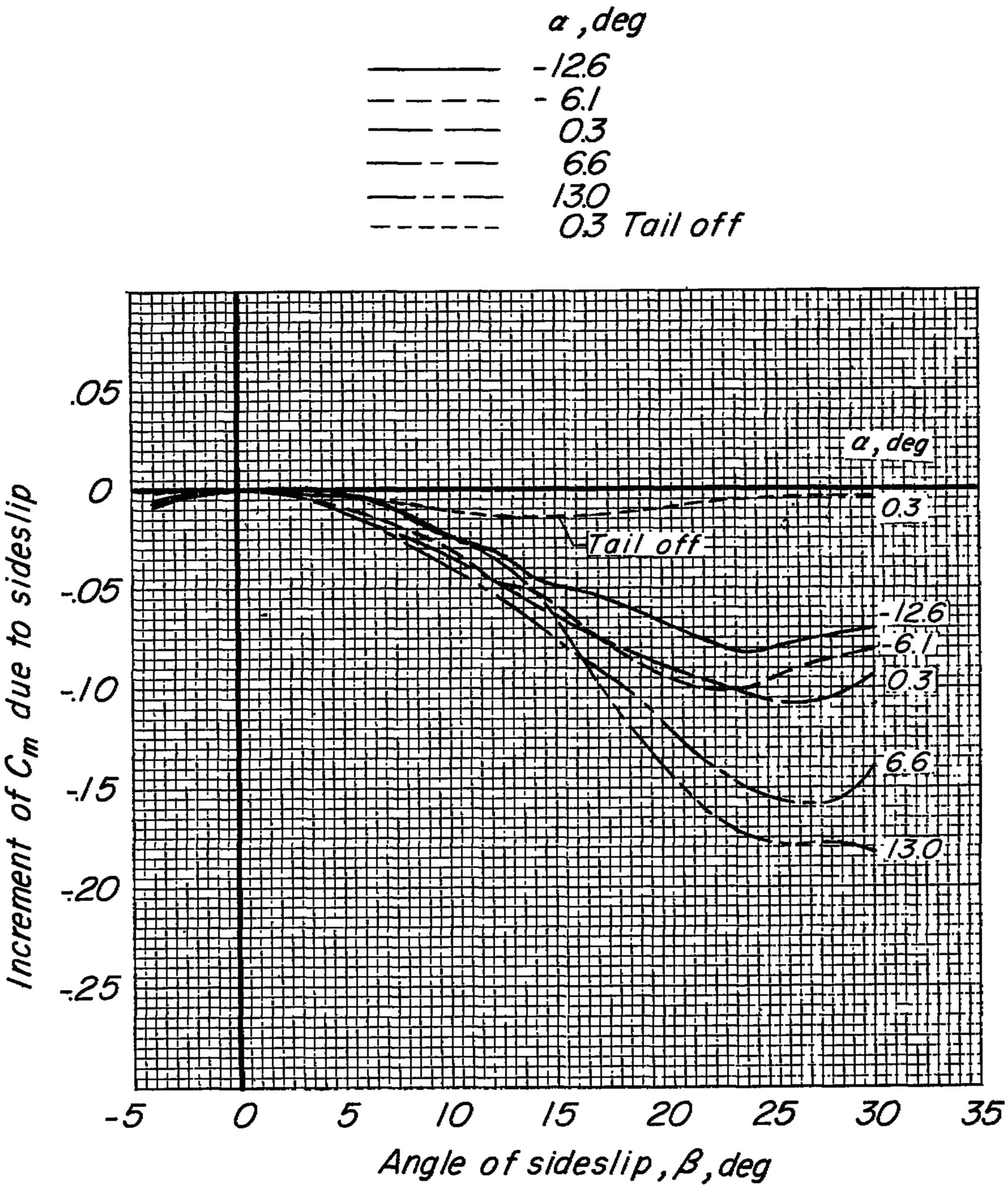


Figure 19.- Effect of angle of attack on the increment of pitching moment due to sideslip for the model with tanks and brakes installed.

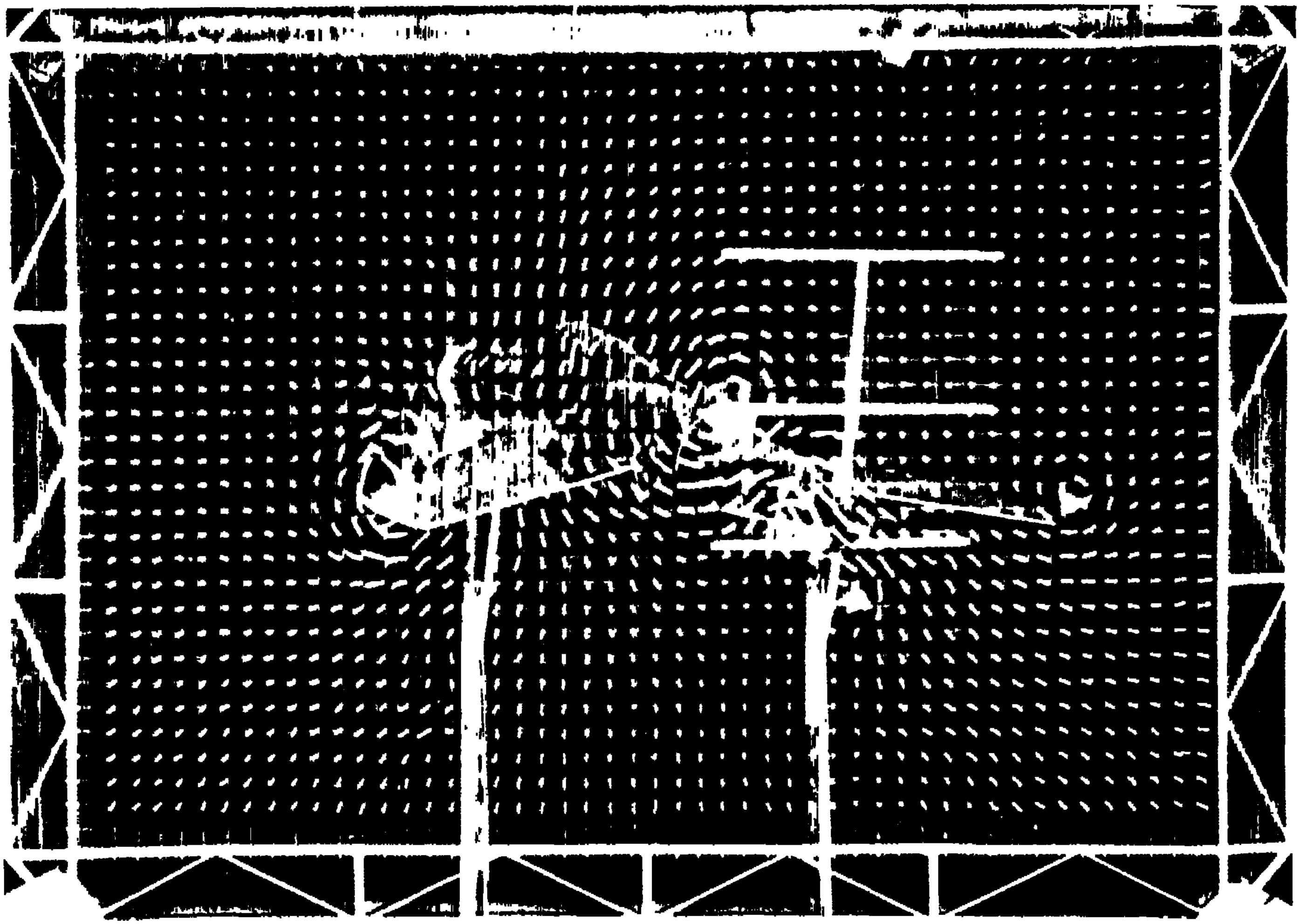


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Figure 20.- Flow field behind the model as indicated by a tuft grid placed in the region occupied by the tip of the tail surfaces. Tail surfaces replaced by thin unswept rods. $\alpha = 10^{\circ}$; $\beta = 25^{\circ}$; basic configuration.

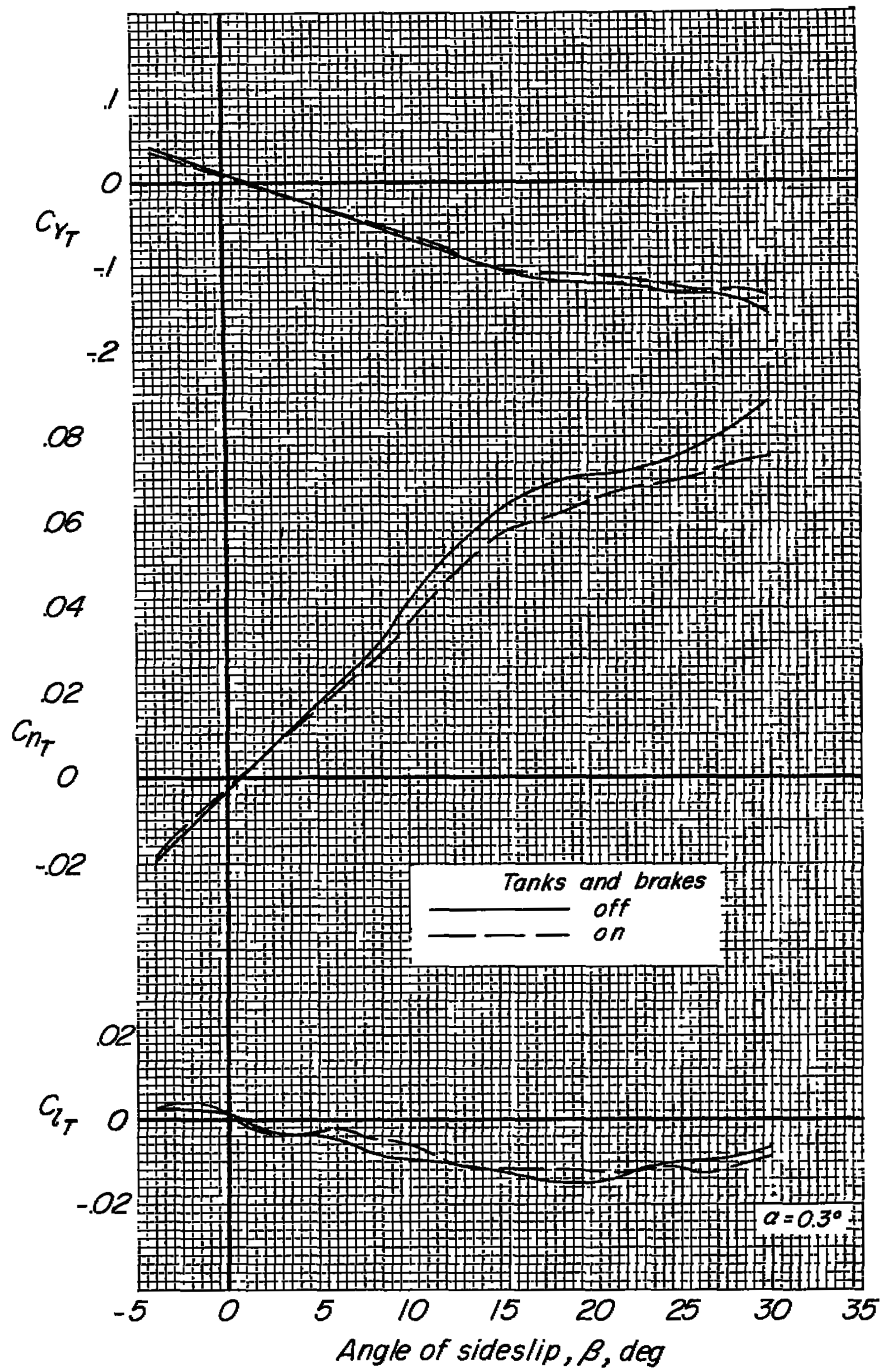

Figure 21.- Effect of tanks and brakes on the increments of the lateral components contributed by the tail surfaces.

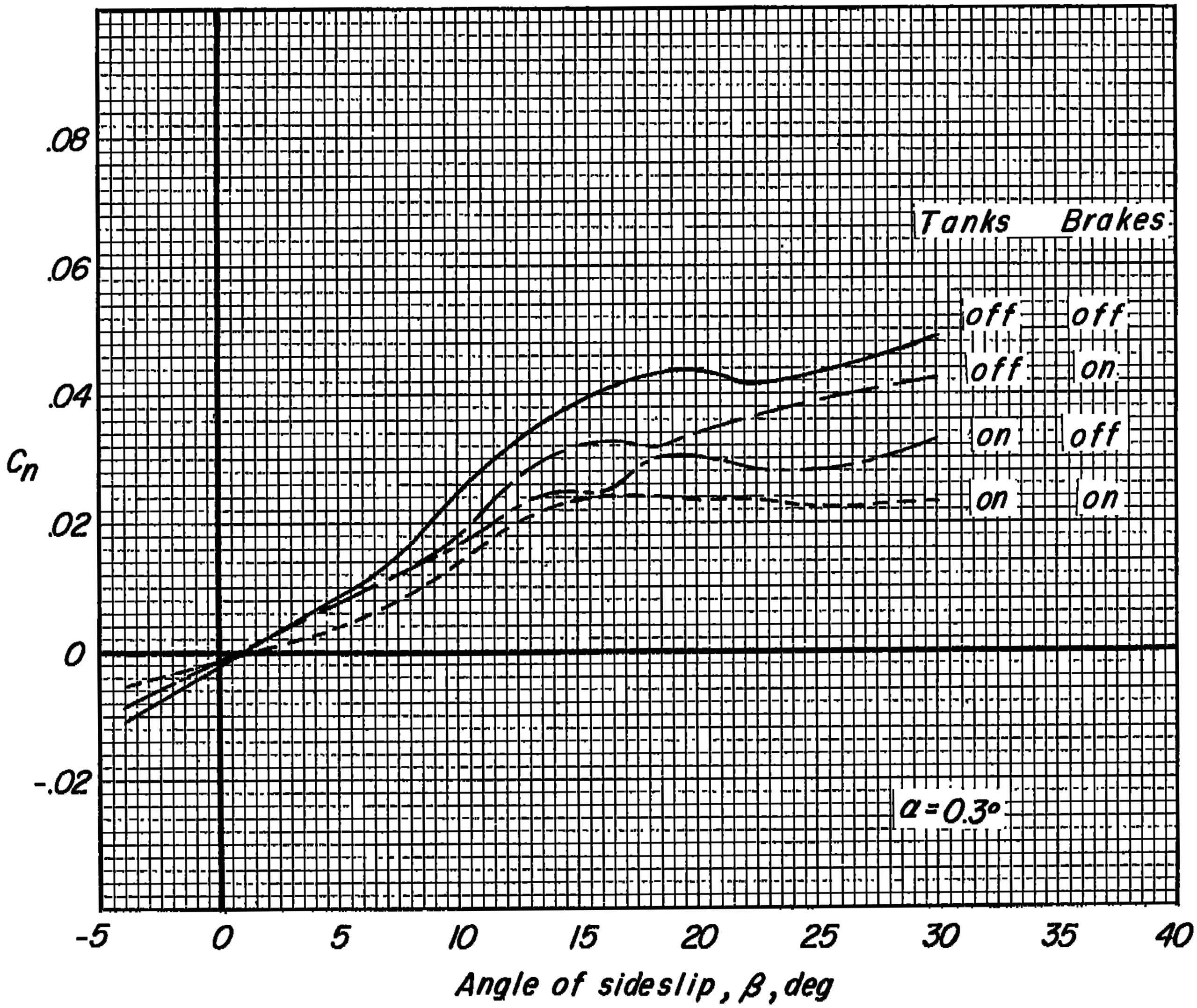

Figure 22.- Separate and combined effects of tanks and brakes on yawing-moment characteristics of the model.

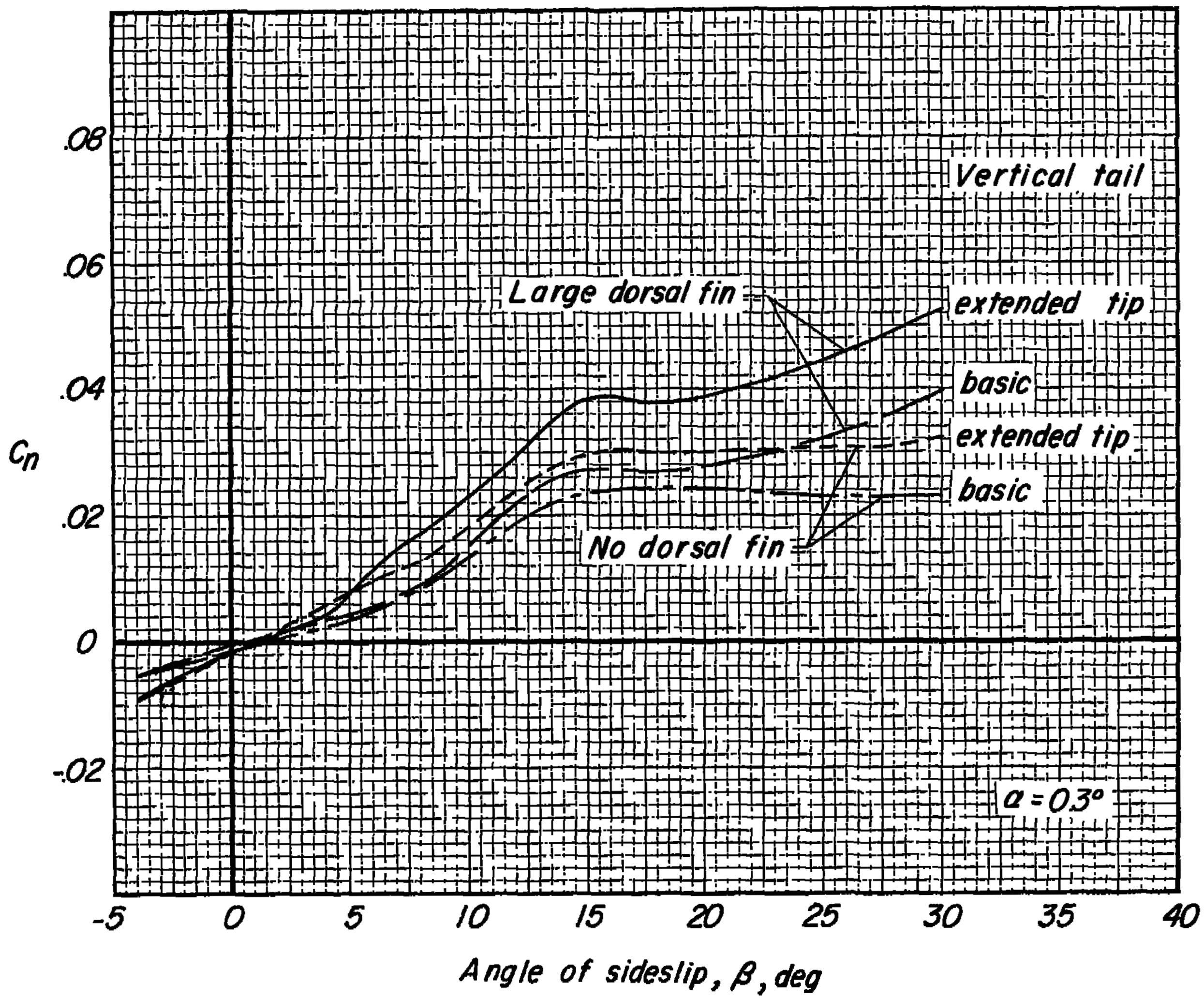

Figure 23.- Summary of the effects of the extended vertical tail and the large dorsal fin on yawing-moment characteristics of the model with tanks and brakes installed.

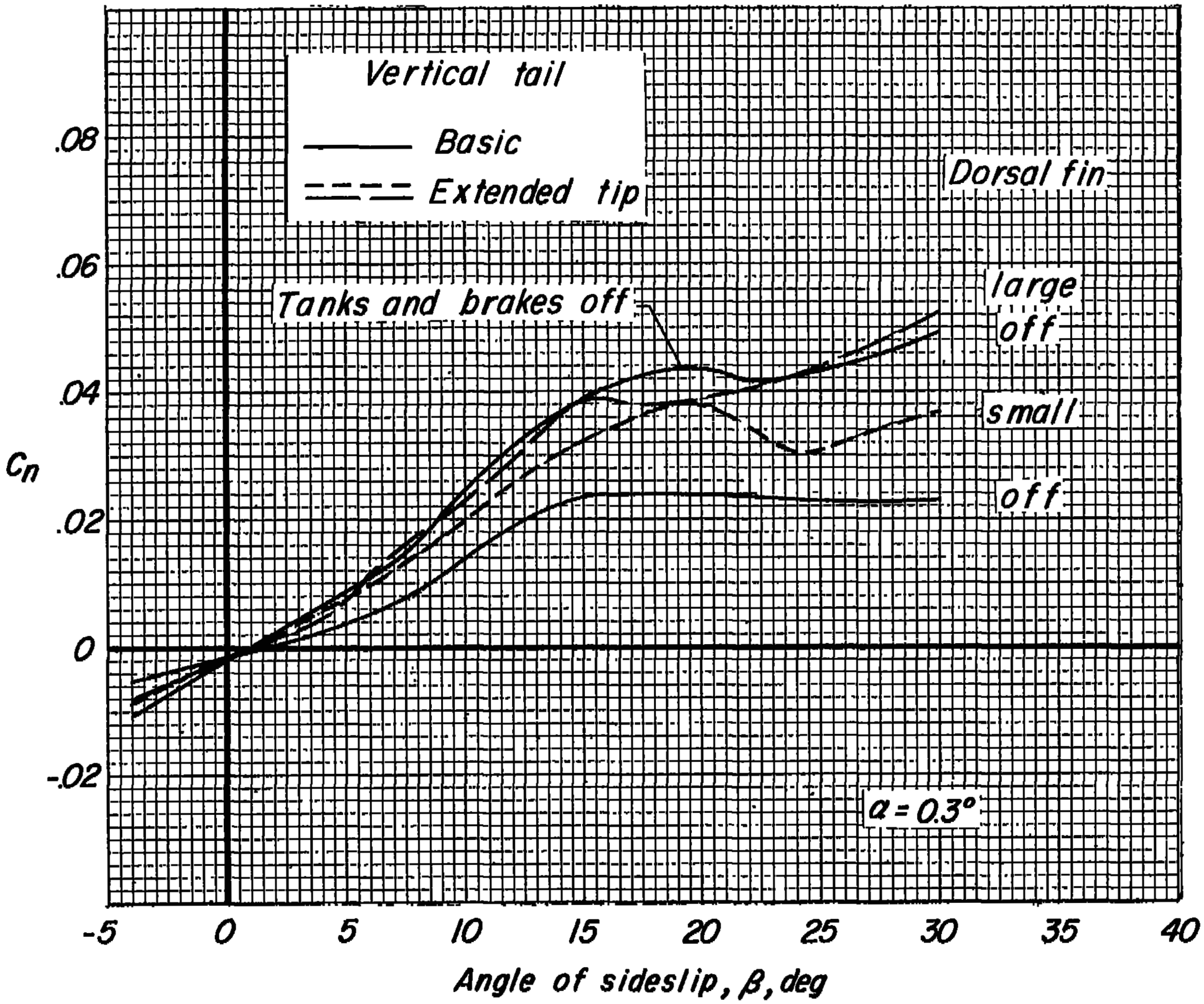

Figure 24.- Summary of the effects of dorsal-fin size on yawing-moment characteristics of the model with tanks and brakes installed.

[redacted]

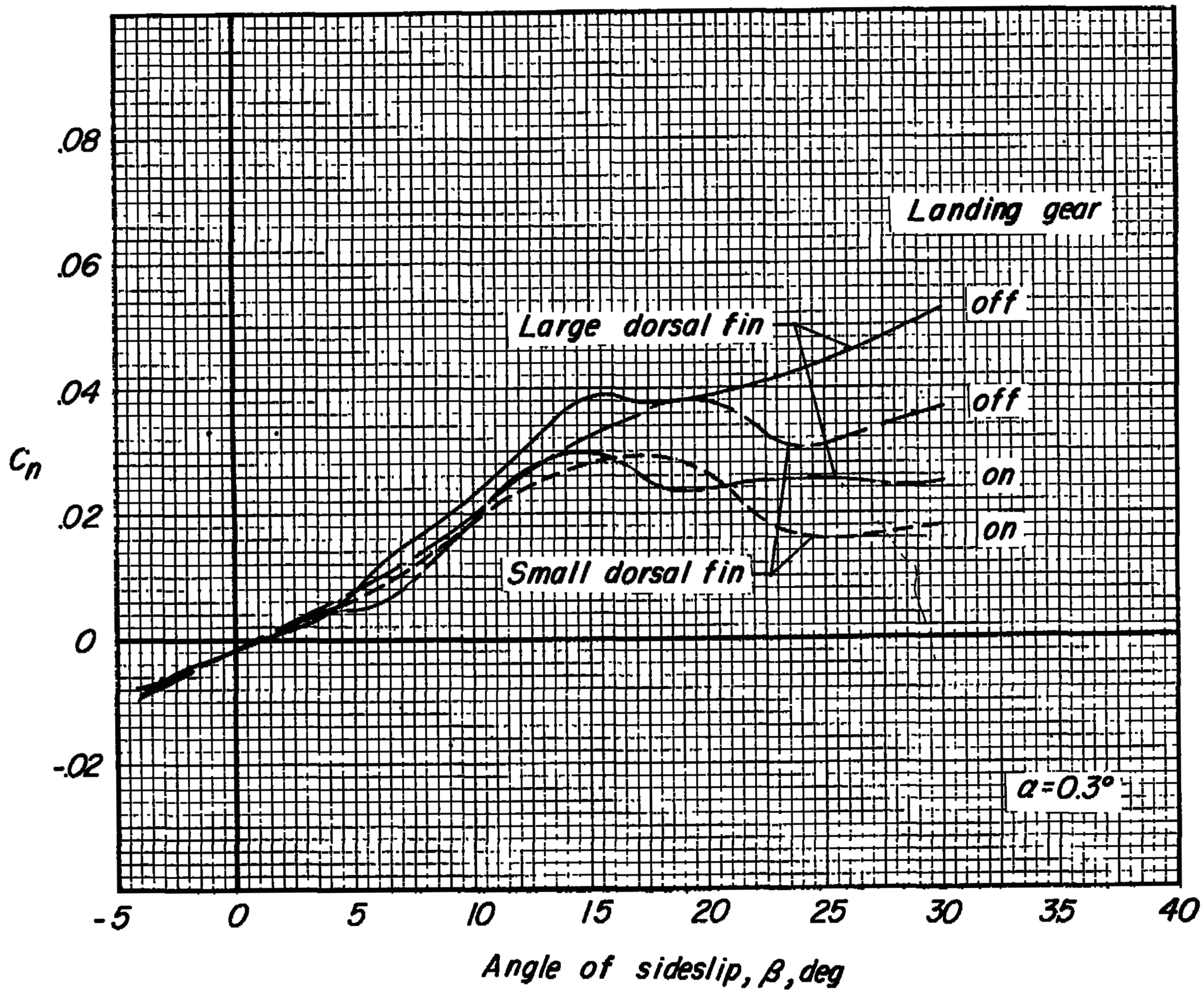

Figure 25.- Effect of the landing gear on yawing moments of the model with tanks and brakes installed.

[redacted]

[redacted]